PB93-152551

Survey and Evaluation of Production Meter Instrumentation and Uses. Report 1

Texas A and M Univ., College Station

Prepared for:

Army Engineer Waterways Experiment Station, Vicksburg, MS

Apr 92

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
NTIS

PB93-152551

SURVEY AND EVALUATION OF PRODUCTION METER INSTRUMENTATION AND USES

REPORT 1

BY

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DILIP R. TRIVEDI, M.ENG., GORDON WILKINSON, M.ENG.
AND DANNY O. DE HERT, M.S.

a report from the Texas A&M
RESEARCH FOUNDATION
College Station, Texas

APRIL 1992

REPORT 1 OF 2

CDS REPORT NO. 313

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for

Hydraulics Laboratory
Waterways Experiment Station
U.S. Army Corps of Engineers
Vicksburg, Mississippi 39181-0631

Contract No. DACW-39-89-K-0003

Report 1 of 2

CDS Report No. 313

April 1992

PB93-152551

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

1a REPORT SECURITY CLASSIFICATION: Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S): CDS 313	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION: Center for Dredging Studies; 6b OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station
6c ADDRESS (City, State, and ZIP Code): Department of Civil Engineering, Texas A&M University, College Station, TX 77843-3136	7b. ADDRESS (City, State, and ZIP Code): 3909 Halls Ferry Road, Vicksburg, MS 39180
8a NAME OF FUNDING/SPONSORING ORGANIZATION: Hydraulics Lab, WES; 8b OFFICE SYMBOL (If applicable): HE-E	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code): U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39180	10 SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO

11. TITLE (Include Security Classification)

SURVEY AND EVALUATION OF PRODUCTION METER INSTRUMENTATION AND USES

12. PERSONAL AUTHOR(S)

John B. Herbich, J.Y. Lee, Dilip Trivedi, Gordon Wilkinson, Denny De Hert

13a. TYPE OF REPORT	13b TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Technical	FROM 11-88 TO 3-90	April 1992	

16 SUPPLEMENTARY NOTATION

17. COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The purpose of this research was to evaluate modern instrumentation being used to monitor production on hydraulic suction dredges. Instrumentation covered included flow meters, density gages and production meters. It was desired to determine their accuracy and reliability as reported by dredge operators worldwide. The survey results led to the conclusion that:

a. The number of dredges in the U.S. with instrumentation to monitor production has increased from 7 percent in 1980 to 46 percent in 1989; however, the percentage of dredges equipped with production meters is only 17 percent.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

b. The magnetic flow meter is reliable and relatively maintenance free as compared to the Doppler flow meter. The nuclear density meter is accurate and reliable when installed at the proper location.

c. More than 90 percent of the dredge operators which have measuring equipment agree that the instrumentation is useful in improving production rates and evaluating total solids production.

d. Current literature on dredge production instrumentation is available on several on-line databases which are continuously updated. The Engineering database (ENGI1) of COMPENDUX PLUS in particular contains several relevant articles which are easily accessible.

e. There are several manufacturers of dredge production instrumentation worldwide, who are constantly upgrading their products. Current information on products can be obtained directly from the manufacturers listed in this report.

PREFACE

The research described in this report was conducted as part of the continuing research program in Ocean Engineering and the Center for Dredging Studies at Texas A&M University, College Station, Texas on a project dealing with the accuracy and reliability of production meters.

The principal unit involved in the study was the Center for Dredging Studies (CDS). Key personnel of the CDS unit who authored the report are: Dr. John B. Herbich, Principal Investigator, W. H. Bauer Professor of Dredging Engineering, Professor of Ocean and Civil Engineering and Director of the Center for Dredging Studies; Mr. J. Y. Lee, Research Assistant; Mr. Dilip Trivedi, Research Assistant; Mr. Gordon Wilkinson, Research Assistant and Mr. Danny De Hert, Research Assistant. The report was typed by Ms. Joyce Hyden to whom the authors express their gratitude.

The study was sponsored by the Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi under contract No. DACW-39-89-K-0003 as part of the Dredging Research Program. The Technical Monitor for this project was Ms. Virginia Pankow, whose comments during the course of this research are gratefully acknowledged. The Dredging Research Program manager was Mr. E. Clark McNair, Jr.

Commander and Director of WES during the preparation of this report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

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CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
yards	0.9144	meters
cubic yards	0.7646	cubic meters

EVALUATION OF THE ACCURACY AND RELIABILITY OF PRODUCTION METERS

PART I: INTRODUCTION

Purpose

1. The purpose of this research was to evaluate modern instrumentation being used to monitor production rates on hydraulic suction dredges. The type of instrumentation covered in this study included flow meters, density gages and production meters on all types of hydraulic suction dredges. An attempt has been made to determine their accuracy and reliability as reported by the end users themselves which are the dredge operators. A comparison has also been made between the utilization of this equipment in the United States and in overseas countries.

Background

2. The need for accurate evaluation of production in dredging operations have been evident for a long time. In the 1960's, the dredge operator had at his disposal only the measurement of pump revolutions per minute, power used, suction and discharge pressures to estimate production. The total rate of flow, or the density (or specific gravity) of the solid-water mixtures was not known. The first improvement was the application of magnetic flow meters to the dredging industry - this provided the total rate of flow (water plus solids). The next improvement was the development of a nuclear density gage which provided an instantaneous reading of the density of solid-water mixtures being pumped. Since the magnetic flow meter is relatively expensive, a Doppler flow meter was developed later.

3. The most desired information in an efficient dredging operation is the accurate determination of the amount of solids passing through the dredge pump. A magnetic or Doppler flow meter and a nuclear density gage have been utilized individually by the dredging industry to determine the flow velocity of the slurry and dredged material density respectively. This is still the case on some dredges.

4. Since dredging operations are now much larger, both in volume and cost, a higher degree of accuracy and efficiency is required. As there are no simple relations between pump speed, slurry density, discharge pressure and solids flow rate, it is seldom possible for the leverman or the dragtender of a suction dredge to maximize production rates with only flow velocity and slurry density as indicators of production.

5. The development of a single integrated production metering system represents a higher degree of automation. With this type of instrumentation, the leverman can determine instantaneous values of flow velocity and slurry density and see the manner in which density and flow velocity interact with each other to affect solids production rate. It usually includes a 'totalizer' which gives a continuous indication of total production (project total or shift total), eliminating the need for computations to determine the total production.

6. The data from the flow meter, which measures the total rate of flow of solids, water and gas (dV/dt) and the density meter which measures the specific gravity of the pumped mixture (dM/dV) are fed into the production metering system which indicates the total rate of solids flow in the pipe (dM/dt = dV/dt x dM/dV) either graphically, on analog/digital displays or on cross-point displays.

7. Though the magnetic flow meter and the nuclear density gage are still the most widely used form of instrumentation on dredges, complete production metering and display systems have also been installed on many modern dredges and are contributing measurably to increased solids production.

8. Output signals from the velocity and density meters are often used to control other instruments such as automatic light mixture overboard (ALMO) device.

Description and Mode of Study

8. Addresses of dredging companies worldwide were obtained from the files of the Center of Dredging Studies at Texas A & M University. A comprehensive list of current dredge operators is also included in "World Dredging Mining & Construction", March/April 1989. A survey form was designed and mailed to dredge operators worldwide to evaluate existing instrumentation on their dredges. A sample form is shown on pages 9

through 11. The results from the survey are shown in Tables 1 through 7, which include only those dredges equipped with measuring equipment capable of monitoring production during the dredging process.

9. The research effort described in this report was conducted according to the following sequence:

- *a*. A computerized literature survey.
- *b*. Information obtained from manufacturers of measuring equipment by means of correspondence and plant trips.
- *c*. Field trips to dredges to evaluate the extent of installed instrumentation and its performance.
- *d*. A mail survey to determine the extent of instrumentation on dredges throughout the world.
- *e*. Investigate the accuracy and reliability of instrumentation on dredges from the responses of the survey and field visits.

SURVEY OF PRODUCTION METER USES - INSTRUCTIONS

The Center for Dredging Studies is conducting a study to evaluate the accuracy and reliability of production meters under a USAE Dredging Research Program contract.

The objectives of the study are to evaluate the instrumentation used for measuring production on hydraulic suction dredges.

The purpose of this survey is to find:

a. the extent of instrumentation regularly used on dredges in the United States to measure production,
b. the accuracy of the instrumentation,
c. the reliability of the instrumentation,
d. the extent of maintenance required,
e. the working life of the instrument, and
f. the usefulness of the meter values.

Production meters have been installed on many modern dredges and are being used with varying degrees of success. Dredge production is calculated from values obtained from a slurry flowmeter and a slurry density gage. We would like to identify the types of meters in use. You need not supply information of a proprietary nature, however, we would appreciate as much information as possible so we can reasonably evaluate the use and reliability of production meter values.

Part I is designed to provide a reasonable information profile of the meters you use. Copies have been supplied to answer Part I items for four instruments you may operate. Additional copies may be made if more forms are needed. If you have several meters of the same type (for example, 3 magnetic flowmeters, one of each of your cutterhead dredges) and they all perform in a similar manner, you may summarize your remarks and fill out only one survey set. In this situation please indicate how many meters you are including.

Part II (Items 16, 17) is more general information and need to be answered only once.

Most statements can be completed by circling the appropriate response. Otherwise please supply a brief statement indicating your response. You may be as elaborate or simple as you like and use additional space on the back of these forms if necessary.

How many of your dredges have instrumentation designed to measure or calculate dredge production? ____________

Survey of Production Meter Uses - Part I
(For each dredge, use one column of the below form.)

			Dredge ( )	Dredge ( )	Dredge ( )	Dredge ( )
1. Type	hopper					
	cutterhead					
	plain head					
	dust pan					
	other ( )					
2. Size	pump					
	hopper					
	other ( )					
3. Meter	Flowmeter	magnetic				
		doppler (acoustic)				
		bend (elbow)				
		other ( )				
	Density gages	nuclear				
		S.G. U loop				
		bend (elbow)				
		other ( )				
	Production meters	Solids Optimizer (Ellicott)				
		other ( )				

			Dredge ( )	Dredge ( )	Dredge ( )	Dredge ( )
4. Manufacturer						
5. Year Purchased (if known)						
6. Display		analog				
		digital				
		cross hair				
		graphic				
		other ( )				
7. Unit of measurement	velocity	ft/sec				
		m/sec				
		other ( )				
	density	S.G.				
		g/l				
		kg/l				
		other ( )				
	production	cy/h				
		cm/h				
		tons/h				
		other( )				
8. % Use: Instrument is on line ___% of the time the dredge is in use.						
9. % Reliability: Instrument gives reliable readings ___% of the time it is used.						
10. Frequency of Maintenance		Once a month				
		Twice a year				
		Once a year				
		Other ( )				
11. Frequency of repair		Once a month				
		Twice a year				
		Once a year				
		Other ( )				
12. Rating: On a scale of 1 to 10 with 10 being perfect, how would you rate this instrument?						
13. Modification: Have you made any modifications to this instrument?		Yes				
		No				
14. Do you have an electronics technician on your dredge?		Yes				
		No				
15. Do you have to call the manufacturer for assistance?		Yes				
		No				

Survey of Production Meter Uses -Part II

16. How is the information obtained used by the leverman?
To improve production? Yes___ No___
To increase density of the slurry being pumped? Yes___ No___
Other (specify)______________________________

17. How is the information obtained used by the project engineer (manager)?
To improve production? Yes___ No___
To determine long-term capability of the dredge? Yes___ No___
To evaluate relationship between type of sediments and production? Yes___ No___
To estimate pay quantities? Yes___ No___
For developing long-term records? Yes___ No___
Other (specify)______________________________
____
____

18. Any additional information that you think would be helpful to meet the objective and purpose of this study would be appreciated. (Additional space available on back of page).

19. Name and address of respondent:______________________________
____
____
Telephone ( )______________

20. Thank you for your cooperation.
If it is appropriate, may we refer to you by name in the survey results? Yes___ No___
The survey should be compiled in ___ months. Would you like to receive a copy of the findings? Yes ___ No___
Please send to the following address:
____
____
____
____

John B. Herbich, Ph.D., P.E.
Director, Center for Dredging Studies

PART II: LITERATURE SURVEY

10. A computerized literature survey was conducted at the Sterling C. Evans Library, Texas A&M University and an additional search was made at the Library of the Center for Dredging Studies.

11. The Engineering (ENGI) Section (ENGI 1) Database COMPENDUX PLUS - 70-88/Dec (Engineering Information, Inc. - 1988) was selected for the search. Each record in COMPENDUX PLUS is a reference to a journal article, technical report, engineering society publication, book, conference proceedings or individual conference paper and includes a brief abstract describing the document. The key words used in the search included:

a. Magnetic flow meter.

b. Nuclear density meter or nuclear density gage.

c. Production meter.

d. Bend meter.

e. Doppler sonic flow meter.

A title search from the Science Index and magazine survey were also conducted. The search produced a total of sixty papers and reports.

12. An additional search was made from the 70-89/June Engineering Database with the following key words:

a. Dredging and Automation.

b. Dredging and Measurement.

c. Dredging and Production.

d. Dredging and Meters.

The search produced a total of 406 articles and publications.

13. The articles most relevant to the study were located, reviewed in depth and abstracted. The articles are listed in the Bibliography. A number of articles of particular interest to this project were abstracted and are included in Appendix E.

14. Laboratory evaluation of the accuracy and reliability of equipment utilized for measuring production rates has not been extensive. Some of the important laboratory studies are summarized in this section.

15. Colwell, et al. (1988) presented results of laboratory tests conducted on Ultrasonic flow meters, both Doppler and Transit-time. The performance of the flow meters was examined for a range of slurry flow regimes and particle sizes. The velocities and concentration distributions

of the slurries were known from extensive previous examinations. The results of the study indicated that although the Doppler flow meter measurements were fairly close to the true velocities, it was not suitable for a broad range of slurry flow. The particle diameter affected the penetrating power of the ultrasonic signal and systematic deviations from the true velocities were found, which were related also to the concentration of the slurry. However, it was concluded that for practical applications like dredging, where normal laboratory standards of accuracy are not needed, the flow meters are undoubtedly useful.

16. WES has also conducted laboratory studies (Pankow, 1989) on production meter components. Several density gages and flow meters manufactured by different companies were evaluated for accuracy and reliability in a closed test-loop. Different grain-size materials, slurry concentrations and velocity regimes were utilized for the study. The results indicated that the various nuclear density gages were very consistent in their measurements of density and showed values within 1-5 percent of each other. Although the preferred pipe orientation for density gages is vertical, they perform better when the pipe is rotated 45 degrees from the horizontal. The magnetic flow meters were also fairly consistent in their measurements and showed values within 6 percent of each other. Slurry velocity and slurry concentration had little to no effect on the accuracy of the magnetic flow meters. However, the data for the Doppler Flow meters showed distinct differences among themselves. Though the data for each meter were fairly self-consistent, the Doppler flow meters showed significant differences from the control meter. The magnetic flow meters produced measurements fairly close to those of the control meter. Slurry velocity had some effect on the accuracy of the Doppler flow meter.

17. Process industries have also conducted laboratory evaluations of production meter components (Malone, 1985 and Gilman, 1981) and have realized that slurries are very often highly viscous and are likely to exhibit non-Newtonian behavior. The need to measure flows with Reynolds numbers as low as 300 continues to present difficulties in accurate measurements. The selection of an optimum flow meter relies substantially on the characteristics of the slurry flow like particle size, flow regime, pipe diameter, etc.

18. A production metering system increases the efficiency and economy of the dredging process in terms of optimum use of man and

machinery. Experimental results at the Ellicott test facilities (Wells, 1974) illustrate that the velocity range for maximum production rate, given a fixed line-length, is relatively narrow. As the line-length increases, the velocity range narrows further and without a production metering system it would be difficult for a leverman or a drag tender to regulate the pipeline velocity with any degree of optimization.

PART III: INFORMATION FROM MANUFACTURERS OF MEASURING EQUIPMENT

19. Letters were sent to manufacturers of measuring equipment to identify their products and also to acquire literature describing the instrumentation which is currently available or being used to measure production rates. Names and addresses of manufacturers were obtained from the CDS files and from various magazines and catalogs. A partial list of the products available on the market is presented in Table 8. The manufacturers' claims are compared with the response from dredge operators in Tables 9.1 through 9.4

20. Since there are various types of dredge production meter components available, short descriptions of some of the most widely used types are presented in this section to familiarize the reader with the method of operation of each system.

Magnetic Flow Meter

21. The magnetic flow meter is based upon the principle of electromagnetic induction, designed to measure the flow of conductive liquids in a pipe. Two electromagnetic coils surround a pipe made of anti-magnetic materials and produce a magnetic field at right angles to the flow direction. As a conductive liquid passes the metering section, the lines of force from the magnetic field are cut, producing a low-level voltage at the stainless steel pick-up electrodes. The electrodes measure the potential difference which is proportional to the flow rate and independent of the solids concentration. Both A-C systems and pulsed D-C systems are available; however, for dredging applications the A-C system provides the broadest possibilities.

Nuclear Density Gage

22. The nuclear density gage measures density using the energy-absorption method. A radioactive source, usually Cesium 137 or Cobalt 60, emits gamma-ray energy through the discharge pipe. The rays are absorbed in proportion to the density of the slurry, and a detector either of the Ion chamber or Scintillation type handles the gamma ray energy.

23. The Ion chamber detector is a gas-filled device with a polarizing voltage applied to it. When gamma rays strike the device, the energy ionizes the gas creating a small current which is amplified and sent to the transmitter. Scintillation type detectors are made of certain plastic materials, which give off a pulse of light when struck by gamma rays. A photomultiplier tube converts the light pulses to voltage pulses which are then sent to the transmitter. The transmitted energy is finally converted into a linearized output which indicates density changes.

Doppler Sonic Flow Meter

24. The Doppler flow meter uses the theory of the 'Doppler effect'; i.e. there is an apparent change in the frequency of sound, light or radio waves as a function of motion. These meters consist of a piezoelectric crystal transducer, a Doppler frequency receiver and a transmitter. The transmitter sends a continuous ultrasonic signal at an angle to the direction of flow through the pipe wall and into the liquid stream. The sound waves are reflected by particles, bubbles or other discontinuities in the liquid back to the receiver. The difference between the transmitted and the reflected frequencies, called the 'Doppler shift', is analyzed and the flow rate of the slurry is displayed in velocity units.

Ultrasonic Transit-Time Flow Meter

25. One of the disadvantages of the Doppler sonic flow meter is that there have to exist particles or bubbles entrained in the fluid. The transit-time technique uses two sensors, lined up at an angle to the direction of flow, that pulse alternately. A time-differential relationship proportional to the time required to convey ultrasonic pulses upstream and downstream in the flow is calculated, which is in turn proportional to the process flow velocity. These meters, superior though they are to Doppler sonic flow meters, are more expensive and made for cleaner liquids, and are therefore, not suitable for dredged slurry.

Production Metering System

26. The production metering system features a single display combining both slurry velocity and slurry density. It takes into account the interaction between density and velocity, which affects solids production rate. The data from the flow meter, which measures the total rate of flow of solids, and the density meter, which measures the specific gravity of the pumped mixture, are fed into the production metering system. It indicates the total rate of solids flow in tons of solids per unit time as well as total accumulated production. It also includes a 'totalizer' which gives a continuous indication of total production (project total or shift total), eliminating the need for post-operation computations to determine the total production.

Automatic Light Mixture Overboard (ALMO)

27. It is an installation designed to optimize the hopper filling process by allowing only mixture with a predetermined specific gravity to be loaded. Two valves, which are activated by data received from the density gage and flow meter, are incorporated into the pump delivery system. One of the valves causes light mixture to be discharged overboard while the other directs mixture of adequate density to the hopper. The density values can be preset in accordance with the nature of the dredging process.

Draft and Load Meter

28. The draft and loading monitor supplies data on the draft and the loading of the vessel, which enables the dredgemaster to ensure efficient loading of the hopper. Varying circumstances like sailing distance to the dump site, etc. can also be taken into account. The sensors are pressure transmitters installed fore and aft in the hoppers. Besides data on loading and draft, signals representing loading rates are also transmitted to the monitors. Additional equipment can be installed on vessels equipped with ALMO.

Elbow Meter

29. An elbow meter indicates slurry velocity by measuring the pressure differential between a pressure tap on the inside and a pressure tap on the outside of the discharge elbow. The differential pressure is measured by means of diaphragms and is converted into an electrical signal by a differential pressure transducer. The signal corrects for the slurry density and displays the velocity on a display, which may be analog or digital.

List of Manufacturers

30. Appendix A presents the list of manufacturers approached and Appendix B includes brief descriptions of currently available instrumentation supplied by these manufacturers.

Visits to Manufacturers

31. Visits to two manufacturers (Texas Nuclear, Inc., Austin, Texas and Polysonics, Houston, Texas) were made and summary reports are presented in Appendix D.

PART IV: VISITS TO DREDGES

32. Visits to U.S. Government dredges and private dredges in the Southwest Pass area of the Mississippi Delta were arranged and conducted successfully May 15 through November 13, 1989. Pertinent characteristics of the dredges, arranged in chronological order of the date of visit are shown below:

a. OUACHITA, May 16, 1989

Type	- Trailing suction hopper (4,000 CY, 8,000 HP).
Owner	- Gulf Coast Trailing Company.
Instrumentation	- Magnetic flow meter, nuclear density meter, production meter, load meter.

Dredge OUACHITA is well instrumented and most of the equipment is in good operating condition. The exception is the totalizer which has been used very little due to the many problems encountered; constant maintenance is required. The instantaneous production can be determined from a cross-point display.

b. DAVE BLACKBURN, May 17, 1989

Type	- Cutter Suction (27" discharge pipe, 6,950HP).
Owner	- Bean Dredging Corporation.
Instrumentation	- Magnetic flow meter.

Dredge BLACKBURN has a good system of estimating production in spite of the fact that there is no nuclear density meter available on the dredge. A vacuum gage is used to measure density which appears to be working well. The question remains, however, as to the accuracy of this method. The dredge has most of the instrumentation needed to provide for a fairly good estimate of production. Production is determined from a cross-point display.

c. EAGLE I, May 17, 1989

Type	- Trailing suction hopper (6,300 CY, 11,685 HP).
Owner	- Bean Dredging Corporation
Instrumentation	- Magnetic flow meter, nuclear density meter, load meter.

Dredge EAGLE I plans to discard the nuclear density meter in favor of a vacuum gauge to estimate the density of the material. The production can be determined from a cross-point display.

d. WHEELER, May 17, 1989

Type	- Trailing suction hopper (8,000 CY, 10,500 HP).
Owner	- U.S.A.E. (New Orleans District).
Instrumentation	- Magnetic flow meter, nuclear density meter, production meter, load meter.

Dredge WHEELER. Although being fully automated and instrumented, the full advantage of automation is not utilized because the system shuts down when even one of the sensors is

not working. The production is determined from a cross-point display.

e. McFARLAND, May 18, 1989

Type - Trailing suction hopper (3,140 CY, 6,000 HP).
Owner - U.S.A.E. (Philadelphia District).
Instrumentation - Magnetic flow meter, load meter.

Dredge McFARLAND is a fairly old dredge (constructed in 1964), and does not have a nuclear density meter. Production is estimated by observing the power used. The density of material being pumped and the actual production cannot be estimated with the present instrumentation.

f. ALASKA, May 18, 1989

Type - Cutter suction (30 inch discharge pipe, 9,700HP).
Owner - Great Lakes Dredge and Dock Company.
Instrumentation - Doppler flow meter, nuclear density meter.

Dredge ALASKA apparently made attempts to develop estimates of density, velocity and production; however, for some reason the cross point display was abandoned and apparently the Doppler velocity meter has not been very satisfactory. Production cannot be calculated with the present instrumentation.

g. SUGAR ISLAND, August 1, 1989

Type - Trailing suction hopper (3,600 CY).
Owner - North Atlantic Trailing Company (NATCO).
Instrumentation - Magnetic flow meter, nuclear density meter.

Dredge SUGAR ISLAND is one of four almost identical hopper dredges owned by NATCO. Instrumentation consists of nuclear density meters (Texas Nuclear) installed in vertical lines between the flow meter and the main pump, magnetic flow meters (IHC) installed in vertical discharge lines and drag positioning equipment (Observator).

Nothing has been replaced on the flow meters and all original equipment, since 1986, has performed well. The nuclear density meters, also installed in 1986, are performing well except for two circuit boards which were replaced. Production is estimated by pre- and post-dredging surveys.

h. STUYVESANT, November 13, 1989

Type - Trailing suction hopper (9,180 CY).
Owner - Stuyvesant Dredging Company.
Instrumentation - Magnetic flow meter, nuclear density meter, production meter, load meter.

Dredge STUYVESANT is the largest hopper dredge in the United States; most of the instrumentation is of Dutch origin. One of the magnetic flow meters is inoperative; however, the second one is functioning well. The source strength of the nuclear source had been reduced and the density meters were getting low in their ability to penetrate silt, subsequently sources were installed. The density meters are routinely calibrated every two months (on the average).

33. Several photos taken during the visits are shown on the following pages (Figures 1 through 19). A complete photo album was prepared and submitted to the Sponsor separately.

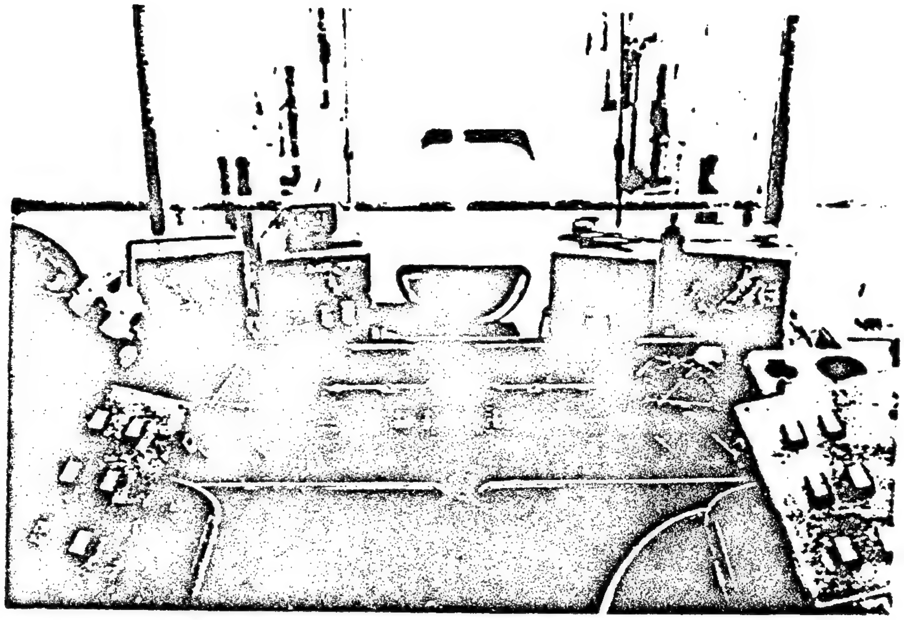


Figure 1. Dredge OUACHITA - Drag Tender Front Display

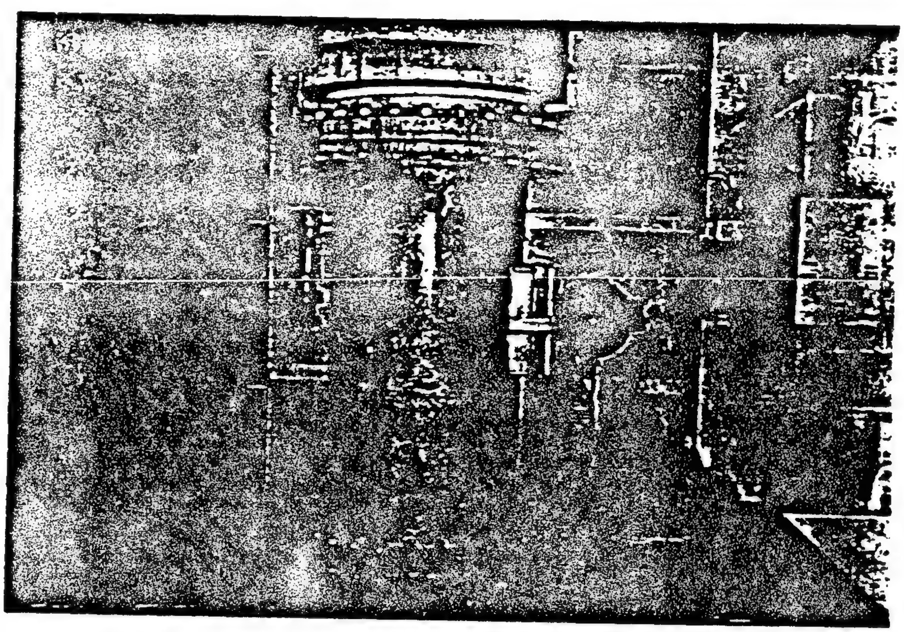


Figure 2. Dredge OUACHITA - Magnetic Flow Meter and Nuclear Density Meter

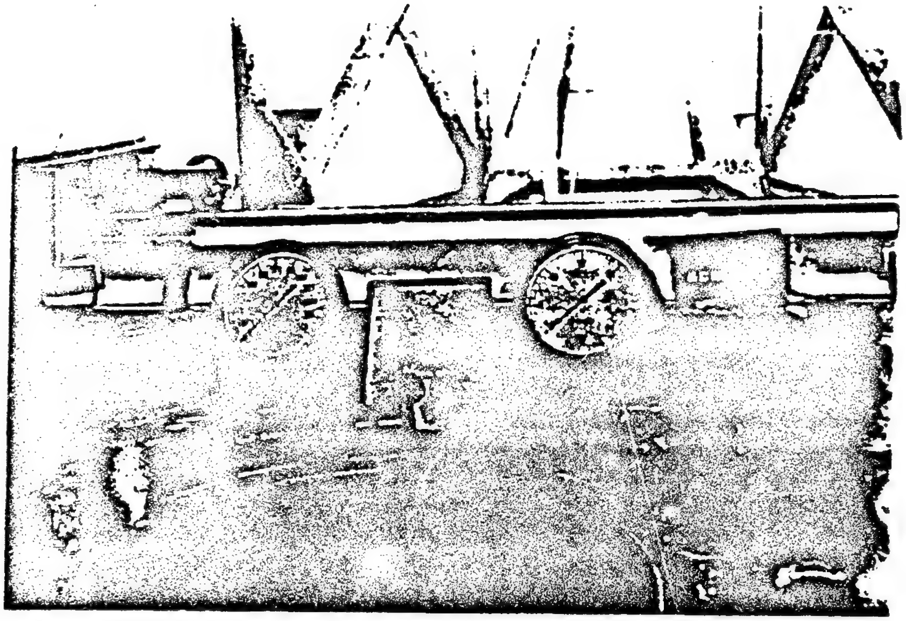


Figure 3. Dredge DAVE BLACKBURN - Drag Tender Front Display

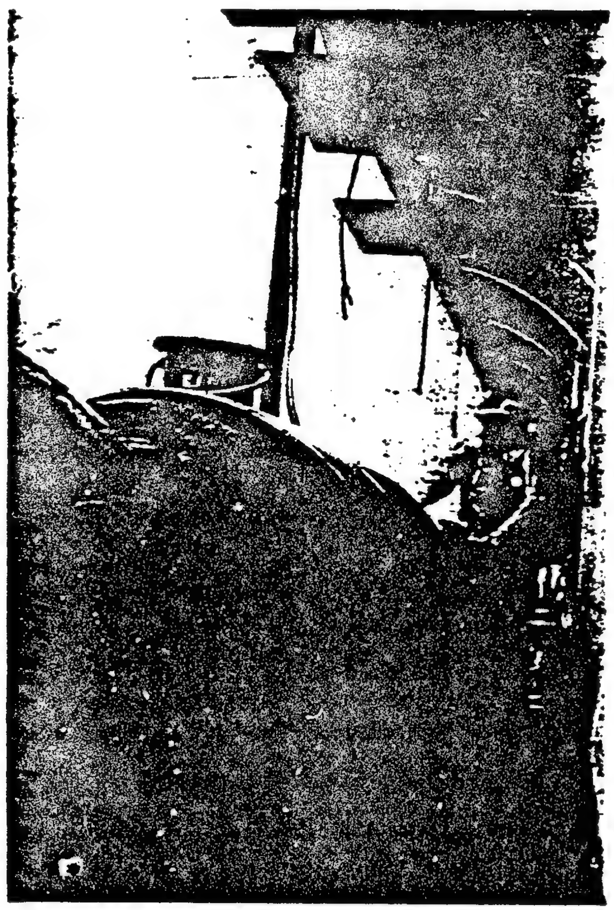


Figure 4. Dredge DAVE BLACKBURN - Magnetic Flow meter in Horizontal Discharge Line

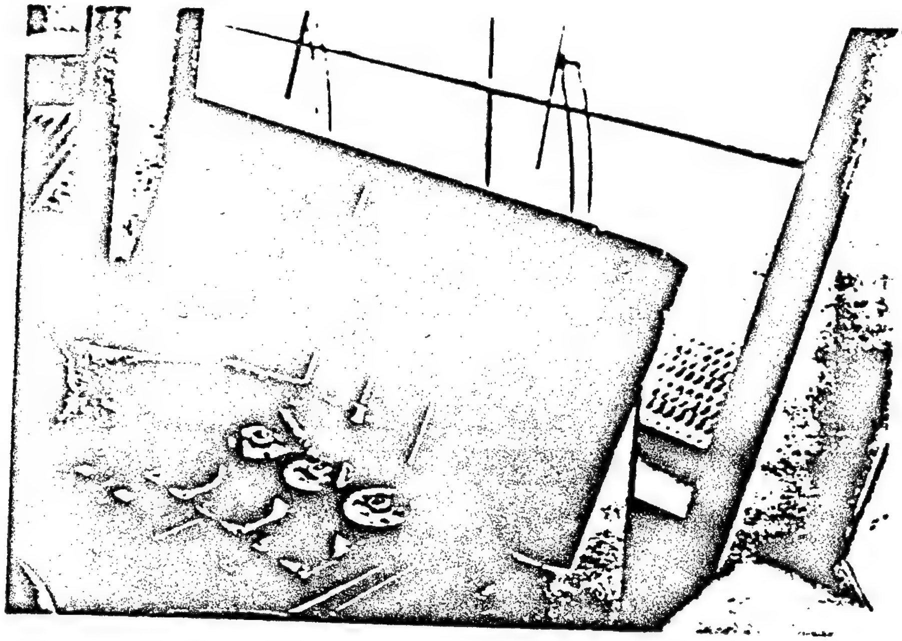


Figure 5. Dredge EAGLE I - Port Side Console

Figure 6. Dredge EAGLE I - Magnetic Flow Meter and Nuclear Density Meter

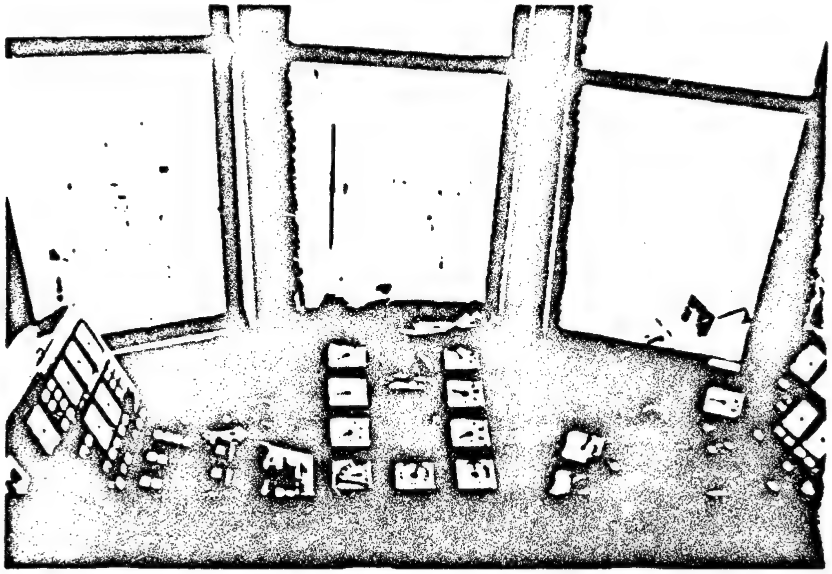


Figure 7. Dredge WHEELER - Drag Tender Control Room

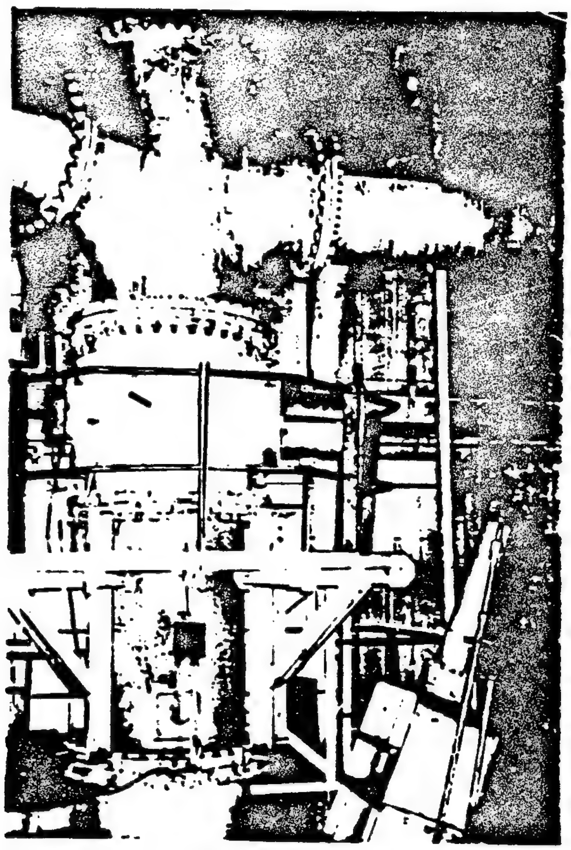


Figure 8. Dredge WHEELER - Center Well Pipe

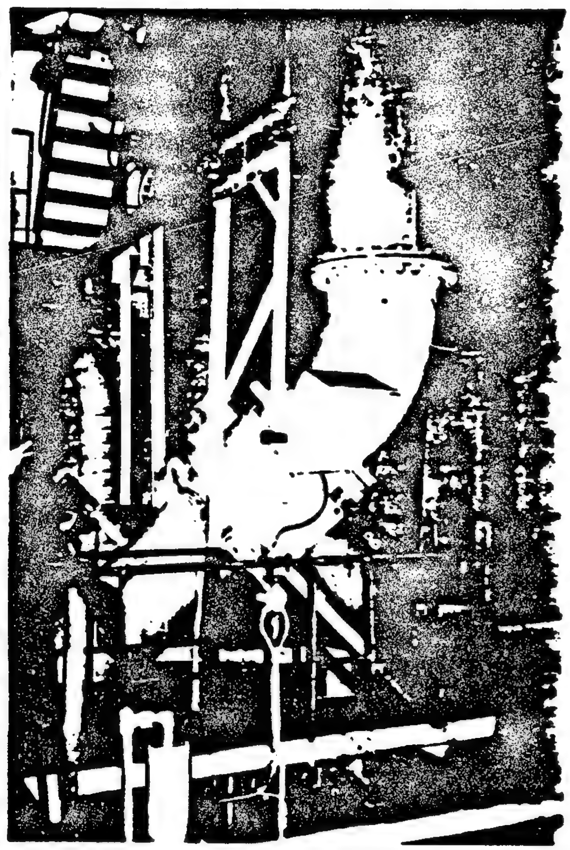


Figure 9. Dredge WHEELER - Port-side Pipe

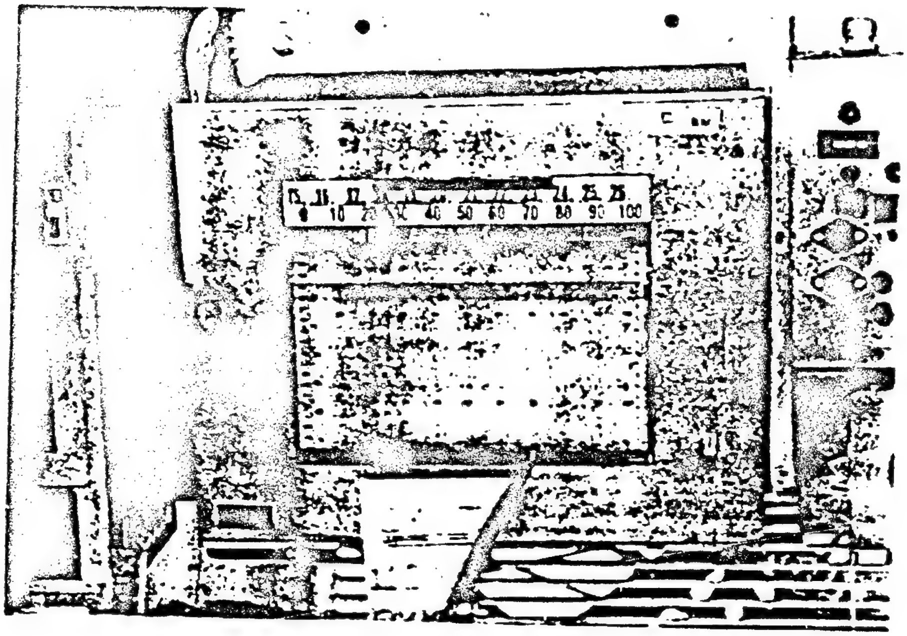


Figure 10. Dredge MCFARLAND - Load Meter

Figure 11. Dredge MCFARLAND - Ship Positioning Radar Display

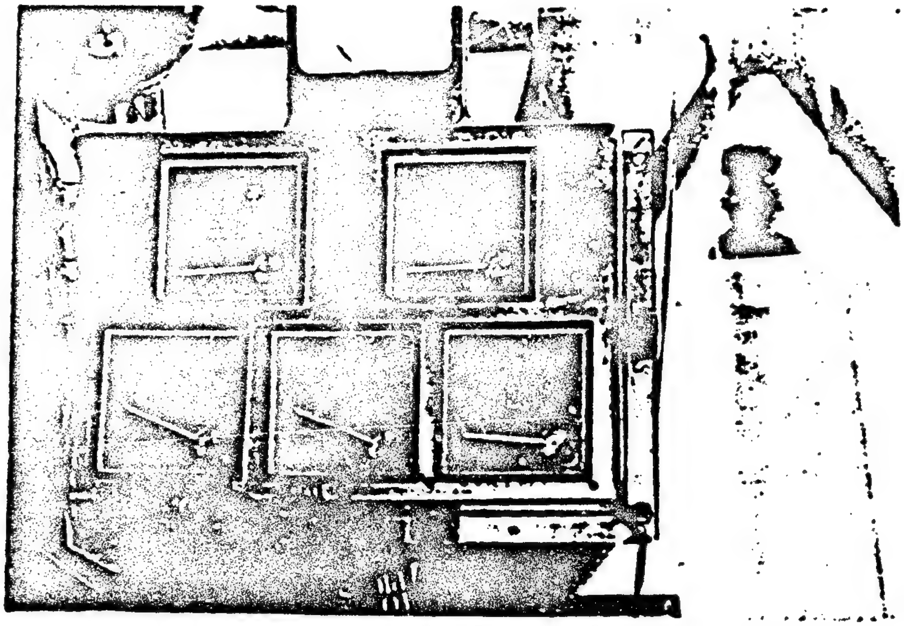


Figure 12. Dredge ALASKA - Drag Tender Control Room Display

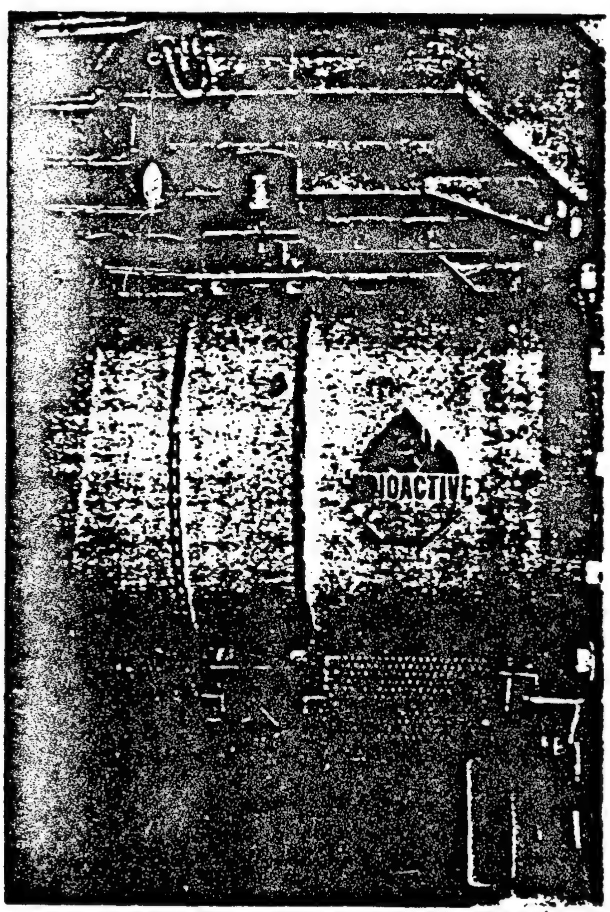
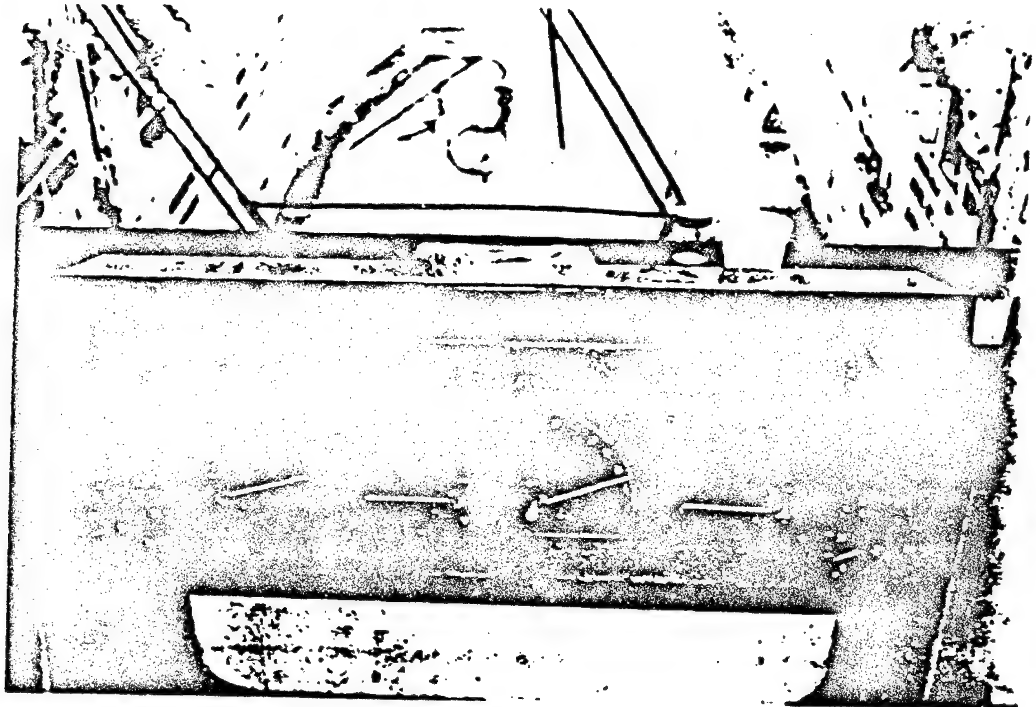


Figure 13. Dredge ALASKA - Nuclear Density Meter

Figure 14. Dredge ALASKA - Doppler Flow Meter



[illegible] Dredge SU[illegible] ISLAND – Dra[illegible] Header [illegible]

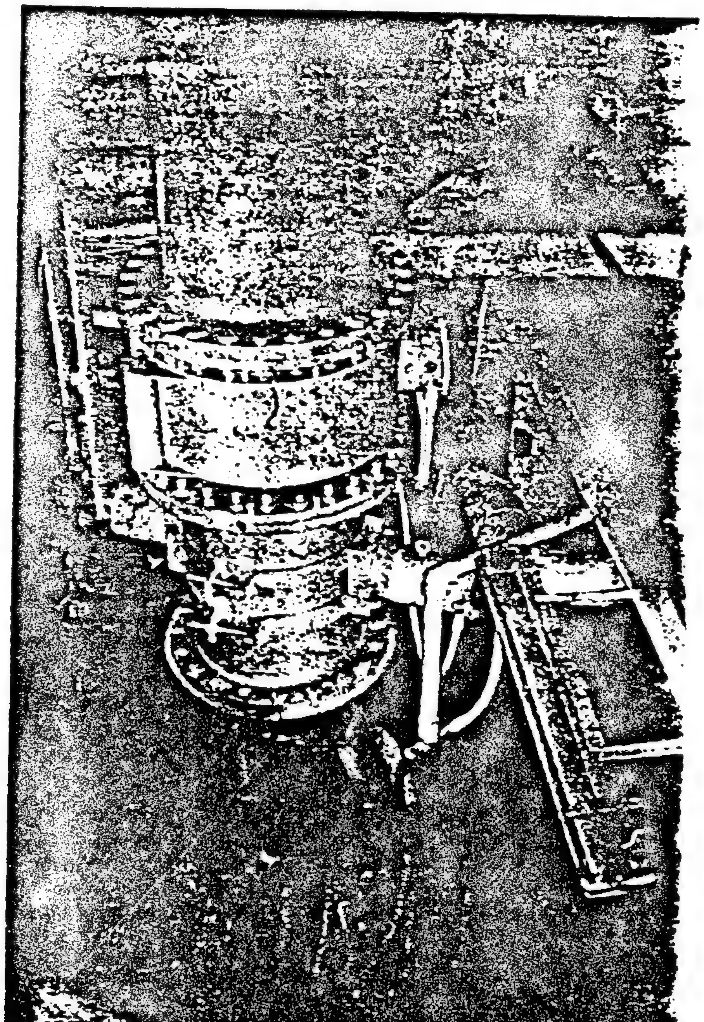
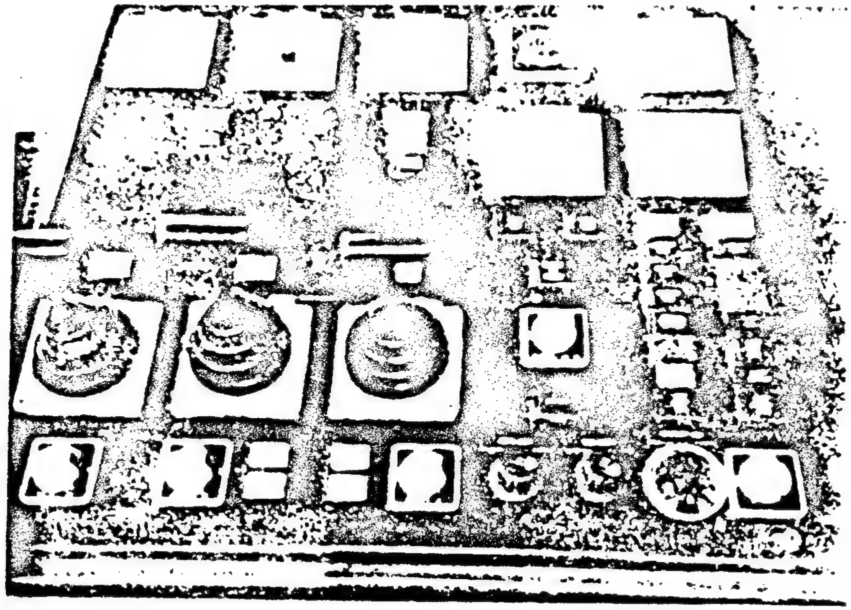
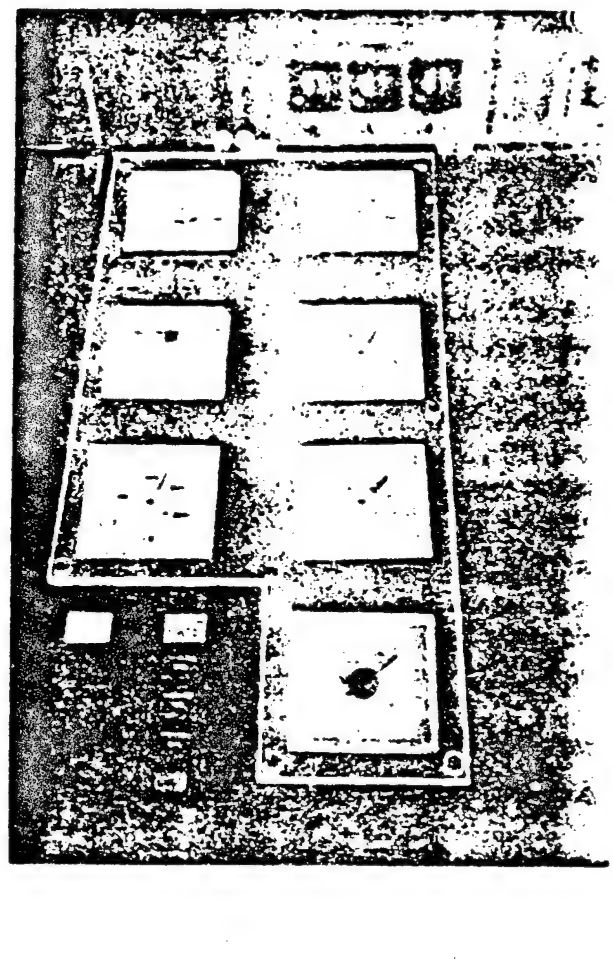


Figure 16. Dredge SUGAR ISLAND – Magnetic Flow Meter and Nuclear Density Meter





RESULTS OF THE SURVEY

signed to obtain the maximum information
ed on dredges for the purpose of measuring
s-water mixture pumped and the discharge
were developed as part of the study; they
of the respondent's time.
were sent to dredging contractors
overseas countries, 186 to contractors in
Districts of the U.S. Army Corps of
vel of response, follow-up letters were
n the U.S. and 31 in the overseas
. contractors, 45 percent of the U.S. Army
it of the overseas countries responded to
that most of the non-respondents do not
own hydraulic suction dredges or do not have instrumentation to measure production or perhaps considered the information proprietary.

36. The complete survey response is shown in Table 1. It should be noted that only those dredges having instrumentation on board to monitor production during the dredging process are included in Tables 2 through 6, whereas Tables 7.1 and 7.2 include the total number of dredges owned or operated by the respondents.

37. Table 2 shows an overall summary of the survey, Table 3 shows the response from the overseas countries and Table 4 shows the response from the U.S. contractors and the U.S. Army Engineer Districts. This summary has been developed for clear presentation of results. Each dredge listed in Tables 3 and 4 is described in more detail in Tables 5 and 6, which include the name and type of dredge, contractor, country or state, the name of the manufacturer or measuring equipment and the year of purchase.

38. A total of 124 dredges are included in this survey. Of these, 72 dredges have some instrumentation to monitor production, including 36 trailing-suction hopper, 33 cutter-suction head, 2 side-caster and 1 suction dustpan. Contractors from 16 overseas and 16 U.S. states responded to the survey.

39. The abstracted summary of survey results for each item is presented below:

a. Flow meter - Magnetic and Doppler flow meters are the major type of measuring equipment in the dredging industry (90 percent, i.e. 65 of a total of 72 dredges). The magnetic flow meter is more popular than the Doppler flow meter in overseas countries as presented in Figure 20. The ratio of magnetic to Doppler is:

Overseas countries - 4.7 to 1 and
U.S. - 0.94 to 1

The number of dredges which have flow meters installed as individual units are:

Overseas - 67 percent (36 of a total of 54) and
U.S - 45 percent (31 of a total of 70).

b. Density gage - The number of dredges which have density gages installed on them are:

Overseas - 67 percent (36 of a total of 54) and
U.S. - 30 percent (21 of a total of 70).

Nuclear density gages constitute the major portion, i.e. 74 percent, of all density gages (53 of a total of 57 density gages) as seen in Figure 21.

c. Production meter - The number of dredges which have installed complete Production Meter Systems are:

Overseas - 63 percent (34 of a total of 54) and
U.S. - 17 percent (12 of a total of 70).

IHC (59 percent) and Texas Nuclear (9 percent) are the major suppliers of this instrument. A number of contractors have integrated flow meters and density gages on their own, using in-house computer software to determine production rates. The results are presented in Figure 22.

d. Display system - The most common forms of display are:

Analog - 66 percent (46 of 70 respondents),
Cross-point - 36 percent (25 of 70),
Digital - 29 percent (20 of 70), and
Graphic - 14 percent (10 of 70).

A number of dredges are equipped with multi-display systems such as digital, cross-point or graphic combined with an analog system.

e. Unit of measurement - The most frequently used units are:

Velocity: Overseas - m/sec (92 percent) and
U.S - ft/sec (97 percent)

Density: Overseas - tons/m3 (71 percent)
- S.G. (26 percent) and
U.S. - gm/l (48 percent)
- S.G. (33 percent)

Production: Overseas - tons/hr (61 percent) and
U.S. - tons/hr (50 percent).

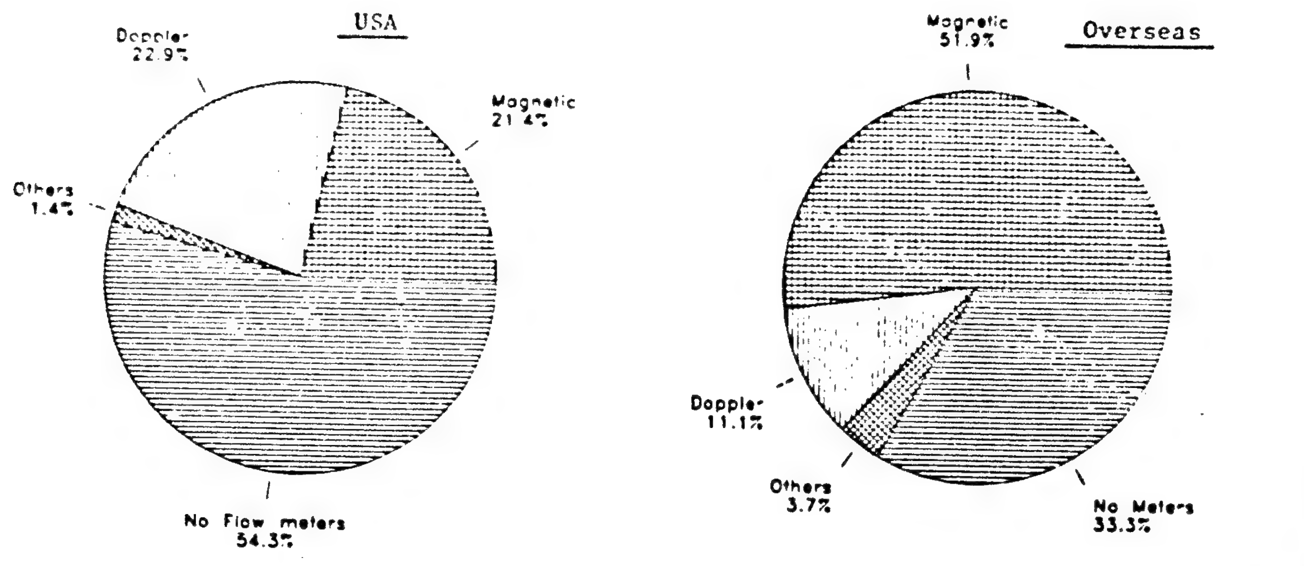


Figure 20. Flow meters

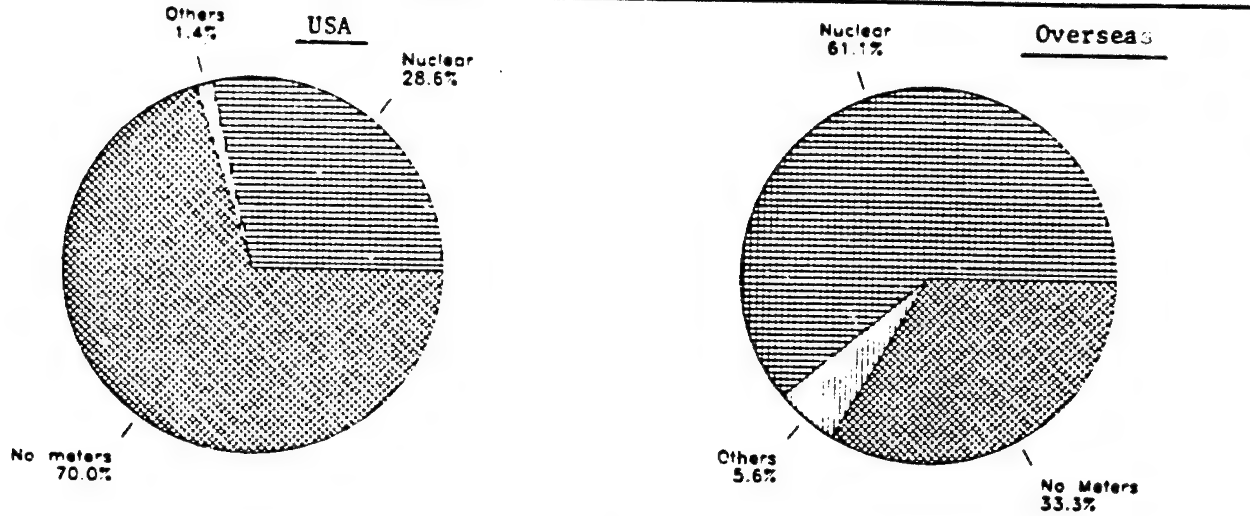


Figure 21. Density Gages

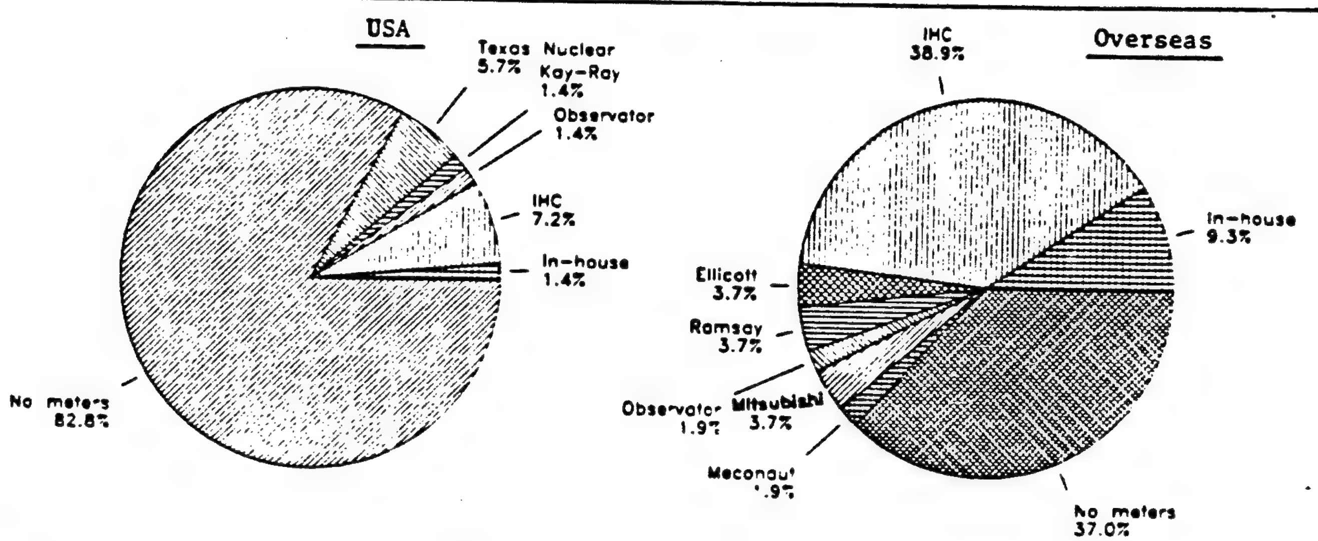


Figure 22. Production meters

f. <u>Time of use</u> - 79 percent of the dredge operators (54 of 68 respondents) use the equipment over 90 percent of the time.

g. <u>Reliability of equipment</u> - 81 percent of the dredge operators (51 of 63 respondents) report a reliability of over 80 percent. Results are presented in Figure 23.

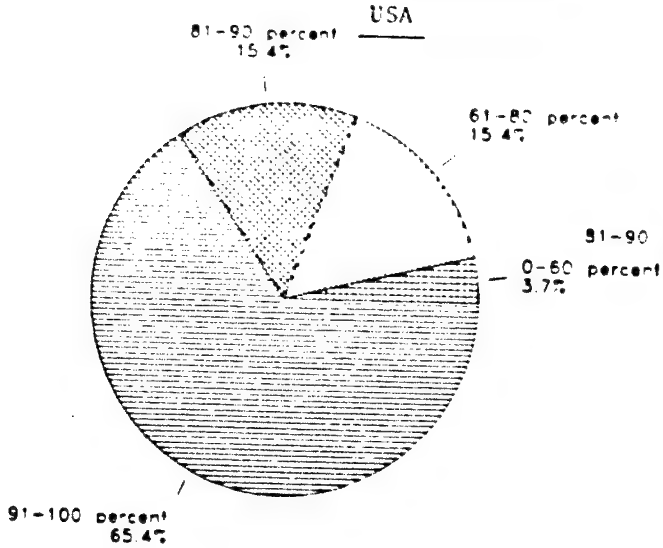
h. <u>Frequency of maintenance and repair</u> - Most of the equipment surveyed was not in need of frequent maintenance or repair. Less than once-a-year maintenance (64 percent), or once-a-year repair (58 percent) was common. Results are presented in Figure 24.

i. <u>Rating of the equipment</u> - On a scale ratio of 1 to 10, where 10 represents excellent equipment and 1 represents very poor quality, 56 percent of the dredge operators report a rating higher than 7 (40 of 60 respondents) as can be observed from Figure 25.

j. <u>Miscellaneous</u>

- 76 percent of the dredges have had no modifications on their original equipment (52 of 68 respondents).
- 69 percent have no electronic technician on board (48 of 70 respondents).
- 74 percent need assistance from the manufacturer of the equipment (51 of 69 respondents).
- 90 percent use the equipment to improve production (65 of 72 respondents).
- 94 percent use the equipment to increase density of the slurry being pumped (68 of 72 respondents).
- 94 percent of the project managers use the equipment to improve production (68 of 72 respondents).
- 69 percent of the project managers use the equipment to determine long-term capability of the dredge (50 of 70 respondents).
- 74 percent of the project managers use the equipment to evaluate the relationship between type of sediments and production (53 of 72 respondents).
- 29 percent of the project managers use the equipment to estimate pay quantities (21 of 72 respondents).
- 67 percent of the project managers use the equipment to develop long-term records (48 of 72 respondents).

40. Compared with the previous survey (Herbich, 1980), the number of dredges with instrumentation to monitor production has increased from 30 percent to 58 percent in a decade. The increase in the U.S. is from 7 percent to 46 percent, while overseas it has remained at a constant 75 percent. The results are tabulated in Table 7.1. The percentage of dredges equipped with complete production meter systems is much higher in the overseas countries (63 percent) as compared to the U.S. (17 percent) which is presented in Table 7.2



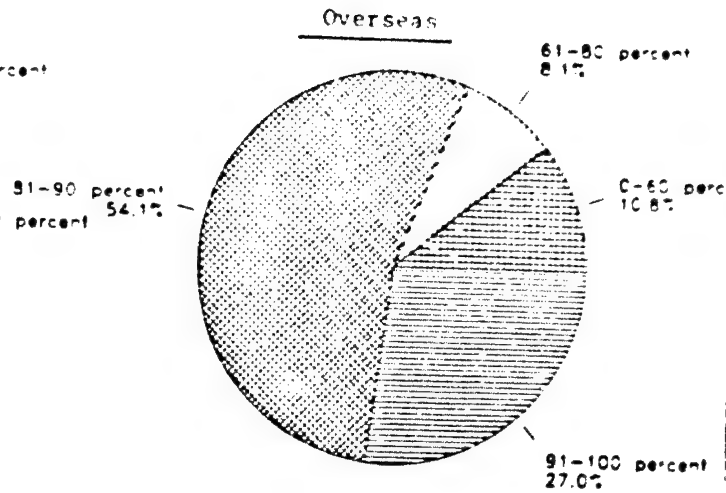


Figure 23. Reliability of Measuring Equipment

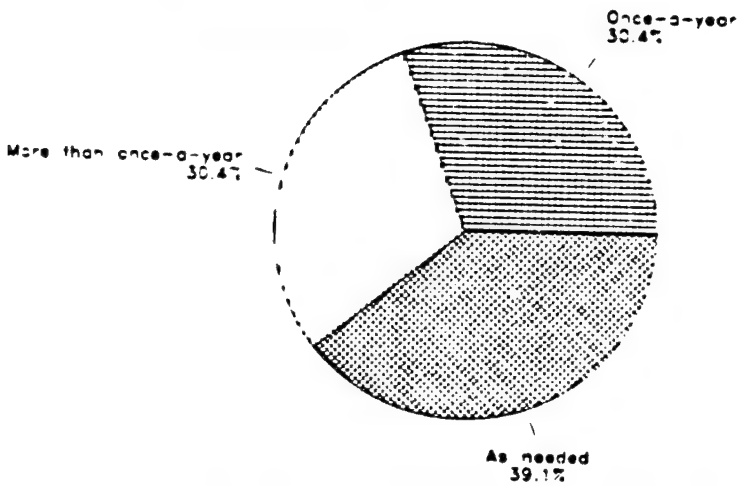
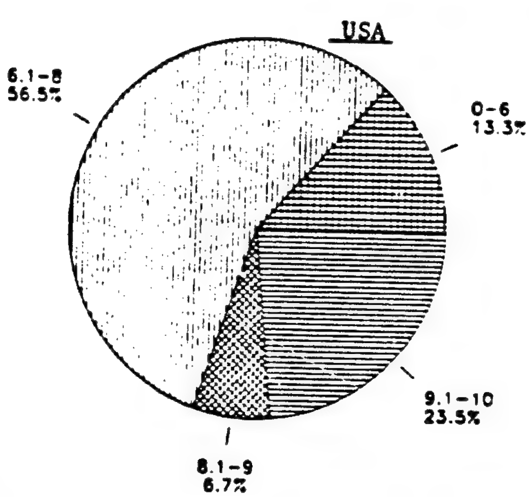


Figure 24. Frequency of Maintenance for Measuring Equipment



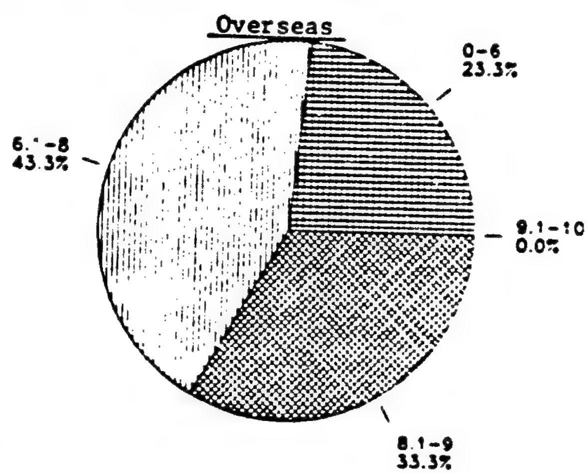


Figure 25. Rating of Measuring Equipment

PART VI: CONCLUSIONS

41. Most modern dredge owners have realized the need for some type of instrumentation that would permit monitoring of production during the dredging process. This can be concluded from the results of the survey, which show that 58 percent of the modern dredges in this survey have some instrumentation on board to monitor production.

42. Complete Production Meter Systems are installed on very few dredges in the U.S. (17 percent). The maintenance or repair of the equipment requires either skilled technicians or assistance from the manufacturer. Wherever they have been installed, the measured production has increased substantially (Wells, 1974), sometimes even by 40 percent.

43. Though the nuclear density gage is reliable, accurate, and safe to use, it employs a radioactive source and a Nuclear Regulatory Commission license is required for its operation in the U.S. Many operators are disinclined to use this type of gage (Pankow, 1989) because of the required training and licensing.

44. With regard to the reliability of the instrumentation, most dredge operators are satisfied with their equipment; 81 percent believe the equipment to be over 80 percent reliable. On a scale ratio of 1 - 10, 67 percent rate the equipment higher than 7. All the dredge operators agree that the equipment is useful in improving production rates and evaluating total solids production.

45. The combination of a magnetic flow meter and a nuclear density gage appears to be more popular than that of a Doppler flow meter and a nuclear density gage, more so among overseas contractors. This can be inferred from the fact that 75 percent of the dredges having both a flow meter and a density gage are equipped with a magnetic flow meter and a nuclear density gage (overseas -- 82 percent, and U.S. -- 62 percent). Experimental results (Pankow, 1989) have also indicated that the most reliable instruments are the magnetic flow meter for slurry velocity and the nuclear density gage for density measurement.

46. A number of dredges have both flow meters and density gages but lack production meters. A majority of such dredge operators integrate the output from the two devices and calculate the production rate and accumulated production by using 'in-house' software as indicated in the responses of the survey.

47. With regard to any inherent problems with the instrumentation, the magnetic flow meter is for the most part reliable and maintenance-free. However, most dredge operators would like to see the life of the lining improved. The polyurethane lining has been substituted with a basalt lining on some meters, however no comments were received from the dredge operators with regard to the life-expectancy of the new liners. No major problems were reported for the nuclear density gage; it is found to be very reliable provided it is installed at the proper location on the pipe and is electronically calibrated every 9-12 months. Since density changes in the flow are not transmitted instantaneously, the dredge should ideally be equipped to measure density as near the suction inlet as possible. Instruments in use currently are installed near the dredge pump (Denning 1971) which result in an output that is delayed by a few seconds after the material has passed the suction head. Cost is the major deterrent for the nuclear density gage as well as the licensing procedure required by the Nuclear Regulatory Commission.

48. The Doppler flow meter is the most economical type of flow meter, however the accuracy of the meter is sometimes in question (Pankow 1989, DeVries 1986 and Denning 1971); also it may not be suitable for a broad range of slurry concentration (Colwell, et al. 1988) and particle size. A combination of recent improvements are making the Doppler flow meters more accurate and they are gaining acceptance as a reliable method for measuring liquid flows. Some of the recent advancements (Smith 1985) include the following: different operating frequencies, larger transducers, better signal-to-noise ratios and internal frequency standard for easier re-calibration.

49. Some problems have been reported with sophisticated automated systems such as the one installed on the U.S. Army Corps of Engineers' dredge WHEELER. Despite the fact that the instrumentation has the capacity of obtaining a high level of efficiency, full automation is not utilized, the principal reason being that the failure of a single sensor results in a complete shut-down of the entire system. Parts of the system are used individually and they work reasonably well.

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Table 1.
Survey Response

	Overseas	U.S.A	U.S.A.E	Total
Total Number Sent	472	186	11	669
Total Responses Received	53 (11 %)	45 (24 %)	5 (45 %)	103 (15 %)
Responses analyzed$^{(i)}$	15	16	2	33
Responses not analyzed$^{(ii)}$				
- wrong address	21	14	0	35
- no longer in business	9	2	0	11
- no instrumentation	8	13	3	24

(i): Analysis was only conducted if there was an indication that some instrumentation was installed on the dredge
(ii): Total Responses Received = $(i) + (ii)$

Table 2.
Summary of Results - Overall

Survey Item		Overseas 40 dredges	U.S.A. 30 dredges	U.S.A.E. 2 dredges	TOTAL(%) 72 dredges
1. Type	Hopper	21	14	1	36 (50)
	Cutter Head	18	15		33 (46)
	Plain Head				
	Dust Pan		1		1 (1)
	Other	1		1	2 (3)
2. Flowmeter	Magnetic	28	14	1	43 (60)
	Doppler	6	15	1	22 (31)
	Bend(Elbow)				
	Other	2	1		3 (4)
	No Meter	4			4 (5)
3. Density Gage	Nuclear	33	18	2	53 (74)
	S.G. U Loop				
	Bend(Elbow)				
	Other	3	1		4 (6)
	No Meter	4	11		15 (20)
4. Production Meter	Ellicott	2			2 (3)
	IHC	21	4	1	26 (36)
	Texas Nuclear		3	1	4 (6)
	Other	11	3		14 (19)
	No Meter	6	20		26 (36)
5. Display System*	Analog	21	24	1	46 (64)
	Digital	11	7	2	20 (28)
	Cross Point	20	3	2	25 (35)
	Graphic	4	5	1	10 (14)
	Other		2		2 (3)
6. Velocity Measurement	ft/sec	3	28	2	33 (46)
	m/sec	34	5		39 (54)
	Other				
7. Density Measurement	S.G.	9	6	1	16 (22)
	gm/l		9	1	10 (14)
	tons/m^3	25	1		26 (36)
	Other**		4	1	5 (7)
8. Production Measurement	yd^3/hr		7	1	8 (11)
	m^3/hr	1	2		3 (4)
	tons/hr	22	8		30 (42)
	tons/sec	9	1		10 (14)
	m^3/sec	11			11 (15)
	Other	2	2	1	5 (7)

Sheet 1 of 3 * multiple display systems on many dredge

Table 2. (Continued)

Survey Item		Overseas	U.S.A.	U.S.A.E.	TOTAL(%)
9. Time of Use	0 ~ 60 %	3	4		7 (10)
	61 ~ 70 %				
	71 ~ 80 %	6			6 (8)
	81 ~ 90 %	1			1 (1)
	91 ~ 100%	27	25	2	54 (75)
	No Response	3	1		4 (6)
10. Reliability	0 ~ 60 %	4	1		5 (7)
	61 ~ 70 %	1	2	1	4 (6)
	71 ~ 80 %	2	1		3 (4)
	81 ~ 90 %	20	4		24 (33)
	91 ~ 100%	10	16	1	27 (38)
	No Response	3	6		9 (12)
11. Frequency of Maintenance	Once a Month	4	8		12 (17)
	Twice a Year	3	4	1	8 (11)
	Once a Year	11	8	1	20 (28)
	Other*	20	6		26 (36)
	No Response	2	4		6 (8)
12. Frequency of Repair	Once a Month	1			1 (1)
	Twice a Year	15	5	1	21 (29)
	Once a Year	4	7		11 (15)
	Other*	16	14	1	32 (44)
	No Response	4	4		8 (11)
13. Rating on a Scale of 1 to 10 (1 = poor) (10 = perfect)	0.0 ~ 6.0	7	4		11 (15)
	6.1 ~ 7.0	2	7		9 (13)
	7.1 ~ 8.0	11	9	1	21 (29)
	8.1 ~ 9.0	10	1	1	12 (17)
	9.1 ~ 10.0		7		7 (10)
	No Response	10	2		12 (17)
14. Any Modifications Made	Yes	3	11	1	15 (21)
	No	35	18		52 (72)
	No Response	2	1	1	4 (6)
15. An Electronics Technician on Board	Yes	13	8	1	22 (30)
	No	26	21	1	48 (67)
	No Response	1	1		2 (3)
16. Assistance Needed from Manufacturer	Yes	31	18	2	51 (71)
	No	9	9		18 (25)
	No Response		3		3 (4)

Sheet 2 of 3

* answers were varied but the majority were less than once-a-year

Table 2. (Concluded)

Survey Item		Overseas	U.S.A.	U.S.A.E.	TOTAL(%)
17. The acquired information is used by the operator to...					
improve production	Yes	34	29	2	65 (92)
	No	1			1 (1)
	No Response	5	1		6 (8)
increase density of the slurry being pumped	Yes	38	28	2	68 (95)
	No	1			1 (1)
	No Response	1	2		3 (4)
18. The acquired information is used by the project manager to ...					
improve production	Yes	38	28	2	68 (95)
	No		2		2 (3)
	No Response	2			2 (3)
determine long-term capability of the dredge	Yes	30	18	2	50 (71)
	No	4	10		14 (19)
	No Response	6	2		8 (11)
calculate relationship between sediment type & production	Yes	30	21	2	53 (74)
	No	2	7		10 (14)
	No Response	8	2		10 (14)
estimate pay quantities	Yes	12	8	1	21 (30)
	No	19	19	1	39 (54)
	No Response	9	3		12 (17)
develop long-term records	Yes	29	17	2	48 (67)
	No	5	11		16 (22)
	No Response	6	2		8 (11)

Sheet 3 of 3

Table 3.

Summary of Results - Overseas

Survey Item		1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1 Type	Hopper			x				x	x			x	x	x	x	x					x	x			x	x	x	x	x	x	x	x	x	x	x						x
	Cutter Head	x	x		x	x	x				x						x	x	x	x			x	x												x	x	x	x	x	
	Plain Head																																								
	Dust Pan																																								
	Other									x																															
2 Flowmeter	Magnetic		x								x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x		x	x	x	x	x		x	x	x	x	x	x
	Doppler	x				x	x		x	x																									x						
	Bend(Elbow)																																								
	Other							x																					x												
	No Meter			x	x																				x	x															
3 Density Gage	Nuclear	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x		x	x	x	x	x	x	x	x	x	x	x	x
	S.G. U Loop																																								
	Bend(Elbow)																																								
	Other				x	x	x																																		
	No Meter							x																	x	x			x												
4 Production Meter	Ellicott																	x		x											x	x	x			x	x	x	x	x	x
	IHC								x		x	x	x	x	x	x	x						x	x			x	x	x												
	Texas Nuclear																																								
	Other		x			x	x												x			x			x	x				x				x	x						
	No Meter	x		x	x			x		x											x																				
5 Display System**	Analog		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x		x	x			x	x		x											
	Digital								x			x	x	x	x	x	x					x			x	x				x											
	Cross Point	x							x		x	x	x	x				x		x											x	x	x	x	x	x	x	x	x	x	x
	Graphic									x					x	x	x																								
	Other																																								
6 Velocity Measurement	ft/sec					x	x	x																																	
	m/sec	x	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x		x	x	x	x	x	x	x	x	x	x	x	x
	Other																																								
7 Density Measurement	S.G.				x	x	x		x									x	x	x							x	x													
	gm/l																																								
	$tons/m^3$		x	x							x	x	x	x	x	x	x				x	x	x	x						x	x	x	x	x	x	x	x	x	x	x	x
	Other									x																															
8 Production Measurement	yd^3/hr																																								
	m^3/hr		x																																						
	tons/hr	x	x			x	x			x								x	x	x	x						x	x			x	x	x	x	x	x	x	x	x	x	x
	tons/sec			x							x	x	x	x	x	x	x													x											
	m^3/sec									x	x	x	x	x	x	x	x					x	x	x																	
	Other																								x	x															

* Refer to Table 5 for dredge name ** multiple display systems on many dredges

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Table 3. (Continued)

Survey Item		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
9. Time of Use	0 ~ 60 %									x																	x	x													
	61 ~ 70 %																																								
	71 ~ 80 %																																			x	x	x	x	x	x
	81 ~ 90 %		x																																						
	91 ~ 100%			x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x						
	No Response	x						x																					x												
10. Reliability	0 ~ 60 %									x															x	x															
	61 ~ 70 %				x																																				
	71 ~ 80 %		x																		x																				
	81 ~ 90 %			x		x	x		x									x	x	x							x	x		x	x	x	x	x	x	x	x	x	x	x	x
	91 ~ 100%										x	x	x	x	x	x	x					x	x	x																	
	No Response	x						x																					x												
11. Frequency of Maintenance	Once a Month			x	x				x									x																							
	Twice a Year					x	x			x																															
	Once a Year		x								x	x	x	x	x	x	x		x	x										x											
	Other***																				x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
	No Response	x						x																																	
12. Frequency of Repair	Once a Month			x																																					
	Twice a Year				x	x	x		x	x	x	x	x	x	x	x	x	x									x	x													
	Once a Year																								x	x			x	x											
	Other***		x																		x	x	x	x							x	x	x	x	x	x	x	x	x	x	x
	No Response	x						x											x	x																					
13. Rating on a Scale of 1 to 10 (1 = poor) (10 = perfect)	00 ~ 60				x					x								x							x	x								x	x						
	61 ~ 70			x								x																													
	71 ~ 80		x																											x	x	x	x			x	x	x	x	x	x
	81 ~ 90					x	x				x		x	x	x	x	x										x	x													
	91 ~ 100																																								
	No Response	x						x	x										x	x	x	x	x	x					x												
14. Any Modifications Made	Yes					x	x		x																																
	No		x	x				x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	No Response	x			x																																				
15. An Electronics Technician on Board	Yes			x					x		x	x		x		x	x	x	x	x		x							x	x											
	No		x		x	x	x	x		x			x		x						x		x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x
	No Response	x																																							
16. Assistance needed from Manufacturers	Yes	x	x			x	x	x			x	x	x	x	x	x	x	x	x	x	x				x	x	x	x			x	x	x	x	x	x	x	x	x	x	x
	No			x	x				x	x												x	x	x					x	x											
	No Response																																								

*** answers were varied but the majority were less than once-a-year

Sheet 2 of 3

Table 3. (Concluded)

Survey Item		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
17. The acquired information is used by the operator to																																									
improve production	Yes		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x
	No							x																																	
	No Response	x																							x	x	x	x													
increase density of the slurry being pumped	Yes		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	No							x																																	
	No Response	x																																							
18. The acquired information is used by the project manager to ...																																									
improve production	Yes		x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	No																																								
	No Response	x						x																																	
determine long-term capability of the dredge	Yes		x	x	x	x	x				x	x	x	x	x	x	x	x	x	x		x	x	x					x		x	x	x	x	x	x	x	x	x	x	x
	No								x	x											x									x											
	No Response	x						x																	x	x	x	x													
calculate relationship between sediment type & production	Yes		x			x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x		x	x	x	x	x	x	x	x	x
	No								x	x																															
	No Response	x		x	x			x																	x	x	x	x													
estimate pay quantities	Yes					x	x		x	x	x	x	x	x	x	x	x												x												
	No		x															x	x	x	x	x	x	x							x	x	x	x	x	x	x	x	x	x	x
	No Response	x		x	x			x																	x	x	x	x		x											
develop long-term records	Yes			x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x									x	x	x	x	x	x	x	x	x	x	x	x	x
	No		x																		x	x	x	x																	
	No Response	x						x																	x	x	x	x													

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Table 4.

Summary of Results - U.S.A. & U.S.A.E.

Survey Item		1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1. Type	Hopper	x							x			x	x	x		x				x		x		x	x	x	x	x	x		x		
	Cutter Head		x	x	x	x	x	x		x					x		x	x	x		x									x		x	x
	Plain Head																																
	Dust Pan										x																						
	Other																						x										
2. Flowmeter	Magnetic								x	x	x	x	x	x		x						x		x	x	x	x	x	x				x
	Doppler	x	x	x	x	x	x	x							x		x	x	x	x	x		x							x	x		
	Bend(Elbow)																																
	Other																															x	
	No Meter																																
3. Density Gage	Nuclear	x							x			x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x		
	S.G. U Loop																																
	Bend(Elbow)																																
	Other									x																							
	No Meter		x	x	x	x	x	x			x								x											x		x	x
4. Production Meter	Ellicott																																
	IHC											x	x									x					x						
	Texas Nuclear																x	x		x	x		x										
	Other									x				x	x	x																	
	No Meter	x	x	x	x	x	x	x	x		x								x					x	x	x		x	x	x	x	x	x
5. Display System**	Analog	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						x		x	x	x	x	x	x	x	x		x
	Digital									x				x	x		x	x	x		x	x	x										
	Cross Point								x	x								x				x	x										
	Graphic									x				x				x		x	x	x											
	Other											x	x																				
6. Velocity Measurement	ft/sec	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
	m/sec								x	x		x				x			x														
	Other																																
7. Density Measurement	S.G	x							x	x					x		x	x					x										
	gm/l															x				x	x	x		x	x	x	x	x			x		
	tons/m³																												x	x			
	Other											x	x	x		x						x											
8. Production Measurement	yd^3/hr									x		x		x		x	x	x					x			x							
	m^3/hr									x						x																	
	tons/hr							x	x			x		x	x					x	x					x		x					
	tons/sec												x																				
	m^3/sec																																
	Other												x									x										x	

* Refer to Table 6 for dredge name ** multiple display systems on many dredges

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Table 4. (Continued)

Survey Item		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
9. Time of Use	0 ~ 60 %																x		x										x	x			
	61 ~ 70 %																																
	71 ~ 80 %																																
	81 ~ 90 %																																
	91 ~ 100%	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x			x	x	x
	No Response																																
10. Reliability	0 ~ 60 %																													x			
	61 ~ 70 %																			x	x		x										
	71 ~ 80 %															x																	
	81 ~ 90 %	x									x							x											x				
	91 ~ 100%		x	x	x	x	x	x	x	x					x				x			x		x	x	x	x	x			x		x
	No Response											x	x	x			x															x	
11. Frequency of Maintenance	Once a Month	x												x										x	x	x	x	x			x		
	Twice a Year									x										x	x		x						x				
	Once a Year								x		x	x	x		x	x						x										x	x
	Other***		x	x	x	x	x											x	x														
	No Response							x									x													x			
12. Frequency of Repair	Once a Month																																
	Twice a Year									x				x						x	x	x							x				
	Once a Year											x	x		x	x		x														x	x
	Other***	x	x	x	x	x	x		x		x								x				x	x	x	x	x	x			x		
	No Response							x									x													x			
13. Rating on a Scale of 1 to 10 (1 = poor) (10 = perfect)	0.0 ~ 6.0																x			x	x									x			
	6.1 ~ 7.0								x		x	x	x	x		x													x				
	7.1 ~ 8.0		x	x	x	x	x								x			x					x								x		
	8.1 ~ 9.0																		x			x											x
	9.1 ~ 10.0	x						x		x														x	x	x	x	x					
	No Response																															x	
14. Any Modifications Made	Yes		x	x	x	x	x								x			x		x		x		x	x	x	x						
	No	x						x	x	x	x	x	x	x		x	x		x		x							x	x	x	x	x	x
	No Response																						x										
15. An Electronics Technician on Board	Yes	x							x			x	x	x		x		x		x		x											
	No		x	x	x	x	x	x		x	x				x		x		x		x		x	x	x	x	x	x	x	x	x	x	x
	No Response																																
16. Assistance needed from Manufacturer	Yes	x	x	x	x	x	x	x				x	x	x	x	x	x	x		x	x	x	x						x	x			x
	No									x									x					x	x	x	x	x			x	x	
	No Response								x		x																						

*** answers were varied but the majority were less than once a year

Sheet 2 of 3

Table 4. (Concluded)

Survey Item		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
17. The acquired information is used by the operator to ...																																	
improve production	Yes	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	No																																
	No Response																x																
increase density of the slurry being pumped	Yes	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	No																																
	No Response							x									x																
18. The acquired information is used by the project manager to ...																																	
improve production	Yes	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	No																x	x															
	No Response																																
determine long-term capability of the dredge	Yes	x	x	x	x	x	x		x	x	x				x							x	x	x	x	x	x	x			x	x	x
	No							x				x	x	x		x	x	x	x	x	x												
	No Response																												x	x			
calculate relationship between sediment type & production	Yes	x	x	x	x	x	x		x	x	x				x	x			x	x	x	x	x	x	x	x	x	x			x		x
	No							x				x	x	x			x	x														x	
	No Response																												x	x			
estimate pay quantities	Yes									x								x				x		x	x	x	x	x			x		
	No	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x	x		x										x
	No Response																												x	x		x	
develop long-term records	Yes		x	x	x	x	x		x	x	x				x				x			x	x	x	x	x	x	x			x	x	
	No	x						x				x	x	x		x	x	x		x	x												x
	No Response																												x	x			

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Table 5.

List of Dredges Used in the Survey - Overseas

No.	Country or State	Contractor or District	Dredge	Type*	Instrumentation on board** (Manufacturer)	Year Purchased
1	Argentina	Pagliettini	Chapaleo II	CS	DFM and NDM (Texas Nuclear)	1980
2	Argentina	Pentamar S.A	Elepele IV	CS	MFM, NDM (IHC) and PM (Integrated)	1980
3	Australia	Port of Brisbane Authority	Sir Thomas Hiley	TH	NDM only (IHC)	1971
4	Australia	Port of Brisbane Authority	Echeneis	CS	Displacement D.G. (G.H.& J.A.)	1963
5	Australia	W. Davison Pvt. Ltd	John W.	CS	DFM, Weight D.G. and PM (W.Davidson)	1988
6	Australia	W. Davison Pvt. Ltd	Andrew D.	CS	DFM, Weight D.G. and PM (W.Davidson)	1988
7	Australia	Port of Devonport Authority	Port Frederick	TH	Piezometric Pressure Transmitter (WIKA)	1983
8	Australia	Port of Melbourne Authority	A.M. Vella	TH	DFM (Polysonic), NDM and PM (IHC)	1973
9	Australia	Port of Melbourne Authority	April Hammer	SC	DFM (Polysonic), NDM	1973
10	Belgium	S.A. Dragages Decloedt & Fils	Unknown	CS	MFM, NDM and PM (IHC)	1978
11	Belgium	S.A. Dragages Decloedt & Fils	Vlaanderen XX	TH	MFM, NDM and PM (IHC)	1987
12	Belgium	S.A. Dragages Decloedt & Fils	Vlaanderen XXI	TH	MFM, NDM and PM (IHC)	1987
13	Belgium	S.A. Dragages Decloedt & Fils	Pacifique	TH	MFM, NDM and PM (IHC)	
14	Belgium	S.A. Dragages Decloedt & Fils	Efficace	TH	MFM, NDM and PM (IHC)	
15	Belgium	S.A. Dragages Decloedt & Fils	Unknown	TH	MFM, NDM and PM (IHC)	1978
16	Belgium	S.A. Dragages Decloedt & Fils	Unknown	CS	MFM, NDM and PM (IHC)	1977
17	Canada	Miller Dredging Ltd.	M.J. Miller	CS	MFM, NDM and PM (Ellicott)	1972
18	Canada	Miller Dredging Ltd.	King Edward	CS	MFM, NDM and PM (In-house)	1961
19	Canada	Miller Dredging Ltd.	Thoe Miller	CS	MFM, NDM and PM (Ellicott)	1982
20	West Germany	Wasser-und Schiffahrtsdirektion	Nordsee	TH	MFM (Fisher&Porter) and NDM (Frieske&Hoepfner)	1988
21	The Netherlands	Amsterdam Ballast Dredging	Lelystad	TH	MFM, NDM and PM (Meconaut)	1986
22	The Netherlands	Amsterdam Ballast Dredging	Haarlem	CS	MFM, NDM and PM (IHC)	1984
23	The Netherlands	Amsterdam Ballast Dredging	Rozenburg	CS	MFM, NDM and PM (IHC)	1972
24	Philippines	Philippine Ports Authority	Philports D-VI	TH	PM only (Mitsubishi)	1982
25	Philippines	Philippine Ports Authority	Philports D-V	TH	PM only (Mitsubishi)	1982
26	Philippines	Philippine Ports Authority	Philports D-I	TH	MFM, NDM and PM (IHC)	1983
27	Philippines	Philippine Ports Authority	Philports D-II	TH	MFM, NDM and PM (IHC)	1983
28	Taiwan	Kaohsiung Harbor Bureau	Kao Ching	TH	Air Pressure Flow meter and PM (Observator)	1971
29	United Kingdom	Civil & Marine Ltd.	M.V. Camborne	TH	MFM, NDM (IHC) and PM (Calculated)	1981
30	Belgium	S.A. Entreprises J. De Nul	Galilei	TH	MFM, NDM and PM (IHC)	1986
31	Belgium	S.A. Entreprises J. De Nul	Amerigo Vespucci	TH	MFM, NDM and PM (IHC)	1980
32	Belgium	S.A. Entreprises J. De Nul	Vasco da Gama	TH	MFM, NDM and PM (IHC)	
33	Belgium	S.A. Entreprises J. De Nul	James Ensor	TH	MFM (Altometer), NDM (Texas Nuclear) and PM (Ramsay)	1980
34	Belgium	S.A. Entreprises J. De Nul	Sanderus	TH	DFM, NDM and PM (Ramsay)	1984
35	Belgium	S.A. Entreprises J. De Nul	Dick Martens	CS	MFM, NDM and PM (IHC)	1986
36	Belgium	S.A. Entreprises J. De Nul	Hondius	CS	MFM, NDM and PM (IHC)	1979
37	Belgium	S.A. Entreprises J. De Nul	Ortelius	CS	MFM, NDM and PM (IHC)	1980
38	Belgium	S.A. Entreprises J. De Nul	Mercator	CS	MFM, NDM and PM (IHC)	1978
39	Belgium	S.A. Entreprises J. De Nul	Leonardo da Vinci	CS	MFM, NDM and PM (IHC)	1976
40	Belgium	S.A. Entreprises J. De Nul	Marco Polo	CS	MFM, NDM and PM (IHC)	1972

* CS - cutter-suction head
TH - trailing-suction hopper

SH - suction plain head
SC - side caster
SD - suction dust pan

** DFM - Doppler Flow Meter
MFM - Magnetic Flow Meter

NDM - Nuclear Density Meter
PM - Production Meter
D.G. - Density Gage

Table 6.

List of Dredges Used in the Survey - U.S.A. & U.S.A.E.

No.	Country or State	Contractor or District	Dredge	Type*	Instrumentation on board** (Manufacturer)	Year Purchased
1	Illinois	Great Lakes Dredge & Dock Co.	Alaska	TH	DFM and NDM (Texas Nuclear)	1989
2	Kansas	Holliday Sand & Gravel Co.	Randolph	CS	DFM only (Dynasonics)	1986
3	Kansas	Holliday Sand & Gravel Co.	St. Joseph	CS	DFM only (Dynasonics)	1986
4	Kansas	Holliday Sand & Gravel Co.	Edwardsville	CS	DFM only (Dynasonics)	1986
5	Kansas	Holliday Sand & Gravel Co.	Morris	CS	DFM only (Dynasonics)	1986
6	Kansas	Holliday Sand & Gravel Co.	Bonner	CS	DFM only (Dynasonics)	1986
7	Kansas	Miles Sand Co.	No. 1	CS	DFM only (AMMCO)	1982
8	Louisiana	Bean Dredging Co.	Eagle 1	TH	MFM (Alto) and NDM (IHC)	1981
9	Louisiana	Bean Dredging Co.	Dave Blackburn	CS	MFM (Alto), D.G.(developed) and PM (calculated)	1984
10	Louisiana	Bean Dredging Co.	Lenel Bean	SD	MFM only (Alto)	1979
11	Louisiana	Gulf Coast Trailing Co.	Atchafalaya	TH	MFM, NDM and PM (IHC)	1980
12	Louisiana	Gulf Coast Trailing Co.	Mermentau	TH	MFM, NDM and PM (IHC)	1980
13	Louisiana	Gulf Coast Trailing Co.	Ouachita	TH	MFM, NDM (IHC) and PM (Observator)	1985
14	Louisiana	Standard Gravel Co.	CZ-30	CS	DFM (Polysonics), NDM and PM (Kay-Ray)	1987
15	Louisiana	Stuyvesant Dredging Co.	Stuyvesant	TH	MFM, NDM and PM (IHC)	1982
16	Oregon	Portable Hydraulic Dredging Inc.	Dink	CS	DFM and NDM (Texas Nuclear)	1984
17	Oregon	The Port of Portland	Oregon	CS	DFM, NDM and PM (Texas Nuclear)	1985
18	Washington	Chris Berg, Inc.	Super Dragon	CS	DFM only (Ellicott)	
19	Washington	Manson Construction Co.	Newport	TH	DFM, NDM and PM (Texas Nuclear)	1984
20	Washington	Manson Construction Co.	Husky	CS	DFM, NDM and PM (Texas Nuclear)	1982
21	Louisiana	New Orleans District, U.S.A.E	Wheeler	TH	MFM, NDM and PM (IHC)	1981
22	North Carolina	Wilmington District, U.S.A.E	Fry or Merritt	SC	DFM, NDM and PM (Texas Nuclear)	1986
23	Illinois	North Atlantic Trailing Co.	Sugar Island	TH	MFM and NDM	
24	Illinois	North Atlantic Trailing Co.	Dodge Island	TH	MFM and NDM	
25	Illinois	Great Lakes Dredge & Dock Co.	Manhattan	TH	MFM and NDM	
26	Illinois	Great Lakes Dredge & Dock Co.	Padre Island	TH	MFM, NDM and PM (IHC)	1987
27	Illinois	Great Lakes Dredge & Dock Co.	Northerly	TH	MFM and NDM	
28	New Jersey	American Dredging	Unknown	TH	MFM and NDM (Meconnut)	1986
29	New Jersey	American Dredging	Unknown	CS	DFM only (Texas Nuclear)	1980
30	Illinois	North Atlantic Trailing Co.	Long Island	TH	DFM and NDM	
31	New York	NYSDOT-WMD	No. 3	CS	pressure vs time FM (Ellicott)	1978
32	California	Bayside Dredging	Turnabout	CS	MFM (Polysonics)	1981

* CS - cutter-suction head
TH - trailing-suction hopper
SH - suction plain head
SC - side caster
SD - suction dust pan

** DFM - Doppler Flow Meter
MFM - Magnetic Flow Meter
NDM - Nuclear Density Meter
PM - Production Meter
D.G. - Density Gage

Table 7.1
Summary of instrumentation on Dredges

1980*			1989		
U.S.A & CANADA	OVERSEAS	TOTAL	U.S.A & U.S.A.E	OVERSEAS	TOTAL
3/45 (6.7%)**	17/22 (77.3%)	20/67 (29.9%)	32/70 (46%)	40/54 (74%)	72/124 (58.1%)

* "Operating Characteristics of Cutterhead Dredges" Presented by J. B. Herbich at WODCON IX, 1980.

** Percentage indicates the ratio of total respondents having some instrumentation on their dredges vs. total respondents

Table 7.2
Summary of production meters on Dredges

1989		
U.S.A & U.S.A.E	OVERSEAS	TOTAL
12/70 (17%)	34/54 (63%)	46/124 (37%)

Table 8.
Manufacturers of Measuring Equipment

Manufacturer	Doppler Flowmeter	Magnetic Flowmeter	Nuclear Density Meter	Production Meter	Other Meters
FOREIGN MANUFACTURERS					
Alto		x			
Fischer & Porter		x			
Frieske & Hoepfner			x		
G. H. & J. A.					DDG*
IHC	x	x	x	x	
Meconaut		x	x	x	
Mitsubishi				x	
W. Davidson	x			x	WDM**
Ramsay				x	
MANUFACTURERS IN U.S.A.					
AMMCO	x				
Dynasonics	x	x			
Ellicott***	x		x	x	
Kay-Ray/Sensall			x	x	
Motorola				x	
Parametrics	x				
Polysonic	x				
Texas Nuclear	x		x	x	

* Displacement Density Gage
** Weight Density Meter
*** Production discontinued. Ellicott now handles sale of IHC equipment

Table 9.1
Characteristics of Magnetic Flow Meters Covered in This Survey

Manufacturer	Size available (pipe O.D.)	Accuracy claimed (% F.S.*)	Accuracy reported (% F.S.*)	Maintenance required (months)	Reliability reported (%)
Alto			70-95	2-12	80-100
Dynasonics**	11/4"-48"				
Fischer & Porter				18	80
IHC			70-95	2-12	80-100
Meconaut	> 3/8"	> 99.5	70	3	85-98

* F.S. – full scale
** mag probe integral transmitter

Table 9.2
Characteristics of Doppler Flow Meters Covered in This Survey

Manufacturer	Size available (pipe O.D.)	Accuracy claimed (% F.S.)	Accuracy reported (% F.S.)	Maintenance required (months)	Reliability reported (%)
AMMCO			100		100
Ellicott			90		100
Dynasonics	1"-60"				
Panametrics	> 1/8"	95-98			
Polysonic	any	98	50-80	1-12	90-95
Texas Nuclear	any		50-100	1-6	60-90
W. Davidson			90	6	90

Table 9.3
Characteristics of Nuclear Density Meters Covered in This Survey

Manufacturer	Accuracy claimed (% F.S.)	Accuracy reported (% F.S.)	Maintenance required (months)	Reliability reported (%)
Ellicott		50	6	90
Frieske & Hoepfner			12	80
IHC		70-95	1-12	80-100
Kay-Ray/Sensall	99	80	12	95
Meconaut	0.0001 gm/cm^3	70	3	85-98
Texas Nuclear		50-80	3	60-90

Table 9.4
Characteristics of Production Meters Covered in This Survey

Manufacturer	Accuracy reported (% F.S.)	Maintenance required (months)	Reliability reported (%)
Ellicott	50	6	90
IHC	80-95	3-12	80-100
Meconaut		3	98
Mitsubishi	40	none	20
Motorola	10		30
Texas Nuclear	50-80		70-90
W. Davidson	90	6	90
Ramsay	50-60		90

APPENDIX A: LIST OF MANUFACTURERS

Manufacturer	Instrumentation
Dynasonics P. O. Box 667, Naperville, IL 60540 (312)355-3055	flow meters (ultrasonic, transit-time, insertion type, magprobe magnetic, portable
E.G.& G. Chandler Engineering 7707 E. 38 St. Tulsa, Oklahoma 74145 (918)627-1740	gravitometers, densitometers, pulsimeters
Ellicott Machine Corporation 1611 Bush Street, Baltimore, MD 21230 (301)837-7900	production metering systems
Fischer and Porter Warminster, PA 18974 (215)674-6000	magnetic flow meters
IHC Holland P. O. Box 1, 2960 AA Kinderdijk, Holland	magnetic flow meters, nuclear density meters, production metering systems, load meters, pressure indicators, dredged profile monitors, sedimentation monitors, ALMO, pump controllers
Kay-Ray/Sensall, Inc. 1400 Business Center Drive, Mt. Prospect, IL 60056 (708)803-5100	nuclear density meters, production metering systems
Meconaut BV P. O. Box 222, 3370 AE Hardinseveld Giessendam, The Netherlands	magnetic flow meters, nuclear density meters, production metering systems, load meters, pressure indicators, dredged profile monitors, sedimentation monitors, ALMO, pump controllers, dragarm monitors
Ohmart 4241, Allendorf Drive, Cincinnati, Ohio 45209 (513)272-0131	nuclear density meters
Panametrics 221, Crescent Street, Waltham, MA 02254 (617)899-2719	flow meters (ultrasonic transit-time, portable)

<u>Polysonics</u> P. O. Box 22428, Houston, TX 77227	ultrasonic flow meters
<u>Texas Nuclear</u> Box 9267, Austin, TX 78766	nuclear density meters, ultrasonic flow meters, production metering systems

APPENDIX B: BRIEF DESCRIPTIONS OF CURRENTLY AVAILABLE INSTRUMENTATION

DYNASONICS

a. Ultrasonic Transit-time Flow Meter

i. 1 inch to 60 inch pipes.
ii. Clamp-on transducers.
iii. Can only be used for relatively clean liquids and not for dredging applications.

b. Phase Shift Probe™ Insertion Flow Meter

i. Uses the same principle as the Doppler sonic meter but the probe has to be permanently installed in the pipe, which may pose a problem for dredging.
ii. 1 inch - 48 inch pipes.
iii. Probe has to be positioned at the mean velocity point, typically 1/8 of the internal diameter of the pipe for fully developed turbulent flow.
iv. Uses high frequency reflected ultrasonic beam.

c. Mag Probe™ Integral Transmitter

i. 1-1/4 inch to 60 inch pipes.
ii. Probe-type magnetic flow meter which is installed in the discharge line.

ELLICOTT MACHINE CORPORATION

a. Ellicott Production Meter System (EPMS)*

i. Can be used on any size dredge
ii. Velocity is measured by an elbow meter which converts the pressure differential between the inside and outside of the elbow into an electrical signal.
iii. Effects of pipe friction are eliminated by using the average of two sensor readings.
iv. Measures specific gravity and velocity of water-solids mixture.
v. Digital readout.
vi. Displays instantaneous and accumulated production in short tons of solids.
vii. Records information on a three channel strip-chart recorder.

b. Ellicott Production Meter System (EPMS II)*

i. Single graphical display that automatically combines slurry velocity and slurry density to indicate the production rate to the operator.
ii. Instantaneous and accumulated production.
iii. Measures specific gravity by means of a nuclear density gage and velocity by any type of flowmeter.

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* No longer being manufactured. Supply of parts and service is continuing.

IHC HOLLAND

a. Inductive Flowrate Indicator (Magnetic Flowmeter)

i. Magnetic flowmeter with a section of a pipe made of anti-magnetic material and fitted with a wear-resistant polyurethane liner.
ii. Stainless steel electrodes incorporated into the pipe wall.
iii. Electrical signal is fed to one or more visual instruments.

b. Integrated Concentration and Flowrate Indicator

i. Combines both a magnetic flow meter and a nuclear density meter in a single pipe section.
ii. Length is only slightly greater than the internal diameter of discharge pipe as compared to combined length of separate concentration and flowrate indicators.

c. Production Indicator (Production Metering System)

i. Cross-point display indicator provides quantity in tons of solids/time, density of the material pumped and the velocity in the pipe.
ii. Input data are provided from the nuclear density meter and the flowrate indicator.

KAY-RAY/SENSALL, INC.

a. Nuclear Density Meter

i. Field-mountable.
ii. Factory calibration.
iii. Accuracy up to 1 percent of full-scale range.

b. Density/Mass Flow Measurement System

i. Does not include volumetric flow meter (customer-supplied).
ii. LCD display of mass flow, flow rate, density, totalized mass flow.

MECONAUT

a. Radiometric Density Measuring System (Nuclear Density Gage)

i. Continuous density measurement.
ii. Stainless steel housing or Permacron(R) coated steel.
iii. Accuracy up to 0.0001 gm/cm^3

b. Magnetic-Inductive Flow Meter (Magnetic Flowmeter)

i. Available with pulsed d.c. field or attenuating field.
ii. 3/8 inch to 80 inch diameter and greater.
iii. Neoprene, PTFE (Teflon) liner or polyurethane hard and soft rubber liner.
iv. Measuring error less than 0.5 percent of full-scale range.
v. Linearity error less than 0.1 percent of full-scale range.

c. Production Calculator (Production Metering System)

i. Analog output of production in m^3/hr or tons/hr.
ii. Resettable digital output of shift production.
iii. Digital output of cumulative production.

d. Meconaut Data Processing Program

i. Used for dredging optimization.
ii. Provides visual display of data.
iii. Generates reports on printer and/or video.
iv. Plots data.

PANAMETRICS

a. Ultrasonic Transit-time Flow Meters

i. 1/8 inch to 80 inch and greater pipes.
ii. Accuracy of 2 to 5 percent.
iii. Uses transit-time technique.
iv. Volumetric unit of measurement.

POLYSONICS

a. Doppler Flowmeter

i. Permanently mounted on discharge line.
ii. Accuracy up to 2 percent of full scale range.

b. Doppler Ultrasonic Flowmeter

i. Non-invasive type flowmeter.
ii. No pipe size limitation.
iii. Provides rate of flow and total volumetric flow.
iv. Accuracy up to 2 percent of full-scale range.

c. Portable Ultrasonic Flowmeters

i. Wide range of light-weight compact flowmeters.

TEXAS NUCLEAR

a. Nuclear Density Meter

i. Measures density by energy absorption method.
ii. Automatic source decay compensator.

b. Doppler Sonic Flow Meter

i. Digital readout.
ii. Strap-on mounting without grease or epoxy.
iii. No limitation on pipe size.
iv. If combined with a nuclear density meter, mass flow can be calculated which would provide density, flow rate, totalized mass

flow, solids content, totalized dry solids content and dry solids weight.

c. <u>Production Metering System</u>

i. Cross-point indicator.
ii. Input data are provided from the nuclear density meter and the flowrate indicator.

APPENDIX C: MEMORANDA OF VISITS TO DREDGES

MMEMORANDUM FOR THE RECORD

SUBJECT: Visit to Dredge OUACHITA (trailing suction hoppper, 4,000 CY, 8,000 HP)

We met with Mr. Tim Weckwerth aboard the supply vessel Bayou Chene at the Ellzey Dock in Venice, Louisiana on May 16, 1989. The contractor, Gulf Coast Trailing Company is owned by T. L. James Company with participation from a Dutch Company, HAM, and a Belgium Company, Dredging International. The HAM Company is very much involved with the dredging operation and has an engineer supervising the work. Dredging International is more of a silent partner. The dredge was built under the supervision of HAM and this company has recently bought Volker Stevin, another Dutch dredge company. The dredge was operating at the time under an emergency contract because of a Russian ship that ran aground and partially blocked the channel. This caused sediment from the side of the channel to be transported into the middle of the channel. Three to four ships have run aground subsequent to the grounding of the Russian vessel. It took about three weeks to remove the Russian vessel which was loaded with grain. The grain had to be pumped out before the ship was finally moved. This occurred at the place where the pilots change. The river pilot leaves the vessel and the Gulf pilot boards the vessel. When this happens the ship slows down considerably and does not have the maneuverability required.

The dredge is well instrumented and all equipment was in operating condition. The dredge was built in 1985 at Twin City Shipyard in St. Paul, Minnesota. The production system consists of a nuclear density meter made by Berthold Company, using a Cesium 137 radioactive source (Figure 2). Since the dredge was built, there was a problem with the nuclear source, this was caused by accidentally dropping the unit. The magnetic flow meter is made by Remag and after it was installed there was a problem with the liner; it was damaged by a large rock which also damaged the probes at the same time (Figure 2). The liner was replaced once and the probes were also replaced once since 1985. The cross-point display was replaced once and has been operating for about 3-1/2 years. The totalizer has been used very little because of many problems; it requires constant maintenance.

The hopper loading chart is made by Observator, Rotterdam; the units used are long tons. The hopper capacity is 4,000 cubic yards. When the ship is empty the chart shows 6,675 long tons. This corresponds to about 1,537 tons of silt and about 2,050 tons of sand. The specific gravity of sediment in situ is taken at 1.90.

Another instrument installed on the dredge is a trim and hopper loading gauge showing the draft AP in feet of sea water, the draft FP in feet of sea water and the mean draft displacement in long tons. It is also made by Observator. The vessel shows about 4 foot trim when empty. Other displays include the velocity in the discharge pipe between 6-20 feet per second, density meter between 0.8 and 0.995 long tons per cubic yard. These meters are located behind the mate, -- he has to turn around to look at the meters.

The bubbler system was installed about 8 months ago. Initially, the Observator system was installed, however it did not work due to an obstruction in the lines and damage to the system. The bubbler system is probably less accurate than the initial system; the accuracy is estimated to be about 6 inches, and this is considered adequate. The bubbler system has been performing well.

The drag-tender has cross-point displays placed on a console in front of him. The density of material being pumped is in long tons per cubic yard with a range of 0.75-1.0, the velocity displays are in feet per second from 0 to 30 ft per second and the production is in cubic yards per hour from 100 to 800 cubic yards per hour (Figure 1). There is also a pressure gauge at the main pump with a range of 0 to 60 psi and a vacuum gauge on the main pump with a range from 0 to 30 inches Hg. Other displays include a dredging depth indicator and an angle that the lower pipe makes with the horizontal. We asked the drag tender if he were not to have all this instrumentation in front of him with the exception of vacuum gauge, would he be able to operate the drag arms? He said he would not know how to operate a dredge without proper instrumentation. TV display monitors installed in the drag-tender's area show the davits, trunions, cables, etc. Because the direct view of the cables is obstructed, the TV monitors were installed to help the drag-tender operate with maximum efficiency. One of the many things that the drag-tender watches is whether the cables supporting the drag arm are taut. The ALMO unit is set at 0.82 cubic yards per hour for automatic overboard discharge.

Dredge OAUCHITA was operating between the jetties and discharging material in the Gulf to the west of the main navigation channel. Upon inquiry we found that a great deal of fluid mud is present in the area from about station 1018+60.3 as measured by an echosounding frequency of 208 kHz which indicates the top of the fluid mud layer. The pilots are aware of this. For this reason, Dredge OAUCHITA did agitation dredging for about a month where the material was re-suspended and then carried by river currents to the Gulf. We met with Captain Charles Townsend during our visit.

MEMORANDUM FOR THE RECORD

SUBJECT: Visit to Dredge DAVE BLACKBURN (cutter suction, 27-inch discharge pipe, 6,950 HP)

We met with Mr. Jim Bean, Mrs. Bean and Mr. Ancil Taylor at their office in Belle Chasse, Louisiana on May 17, 1989, and then visited the Dredge BLACKBURN which was tied up in the Southwest Pass of the Mississippi Delta.

The BLACKBURN has a cross point display showing density of the material pumped, velocity in the discharge pipe and the production. The input into the cross point display is computed density rather than measured density. The BLACKBURN has no nuclear density meter. The density is computed using the vacuum gauge reading and the velocity readings. Since the vacuum readings are important for the accuracy of these calculations, these gauges are calibrated every two weeks. It was pointed out that the cost of the nuclear density meter is about $30,000 while the cost of a good vacuum gauge is about $1200-1300. Several gauges are required at various locations.

The magnetic flow meter is made by Alto (Figure 4). Measurements are taken of many variables which should be monitored on any given project, more than 100 channels are available for data acquisition on any particular project or for any particular study. The output is printed every 4 hours and includes the velocity or discharge reading, density, suction pressure, discharge pressure, cutter amperes, port winch amperes, starboard winch amperes, hourly production and effective dredge time.

The operator uses a joy stick to control the operations. Width of cut, depth of cut and centerline deviation from the centerline in degrees are displayed and visible to the operator. The operator also looks at the cross-point display which shows the density, velocity and production. The operator is particularly interested in production values at any given time. Once a week the equipment is maintained and checked. The equipment which was installed in 1984 has been very reliable, and had one breakdown for about 12 hours during that period. Pressure transducers are made by Druck Company. There is a bracket holding the transducer on a pipe and a cable is used to transmit the pressure values to the operator.

The velocity controls are set by the leverman which include the minimum velocity required to maintain pumping and the maximum velocity which is limited by the horsepower available. There are plans to fully automate the dredge BLACKBURN during the next 18-20 months.

MEMORANDUM FOR THE RECORD

SUBJECT: Visit to Dredge EAGLE I (trailing suction hopper, 6,300 CY, 11,685 HP)

We visited the Dredge EAGLE I with Mr. Ancil Taylor after visiting the Dredge BLACKBURN. The dredge is equipped with a cross-point display and the input into the cross point display comes from the nuclear density meter and a magnetic flow meter, both manufactured by IHC Holland (Figure 5). The nuclear density meter has been installed in a vertical pipe and was found to be very reliable and is calibrated electronically every 9-12 months (Figure 6). The magnetic flow meter has also been found to be reliable; a new lining had to be installed once in both of the pipes (Figure 6). The magnetic flow meter liner includes basalt particles and is a replacement for the polyurethane lining. The operators have not been experiencing any problems with the cross-point display. The drag tender indicated that gas in the sediment interferes with the readings so that in areas where gas is present, the readings may not be accurate.

Vacuum transducers have been replaced and need to be calibrated every few years. The transducers were not as accurate as some other type of equipment on the dredge prior to recalibration. The Automatic Light Mixture Overboard (ALMO) unit has some problems, mostly mechanical.

There are two electronic technicians on the dredge, one for each 12 hour shift.

Positioning system on the EAGLE includes the Del Norte transponder; there is a visual display on the monitor within sight of the drag-tender. The drag-tender also has a display of positions of both drag arms. The equipment was manufactured by Observator; it shows the displacement and draft at aft and fore. The displacement accuracy is probably less than two feet, and no problems were encountered with the displacement instrumentation.

As for future plans, the company is thinking about using the vacuum gauge instead of the nuclear density meter. They also find the magnetic flow meter to be most reliable and maintenance-free except when abused by the installers.

MEMORANDUM FOR THE RECORD

SUBJECT: Visit to Dredge WHEELER (trailing suction hopper, 8,000 CY, 10,500 HP)

We visited the U.S. Army Corps of Engineers Dredge WHEELER on May 17, 1989. Mr. Edward A. Morehose, Chief Mate, took us around the dredge and showed us instrumentation of interest to our project. Dredge WHEELER is the most modern, fully-automated and instrumented dredge in the United States, if not in the world. Most of the instrumentation is used to obtain a high level of efficiency; however, full automation is not being utilized. The principal reason being that if just one sensor in the fully automated system fails, the automated system stops working. For example, if a small pressure sensor fails or the signal does not come through from the gauge to the computer, the automatic system shuts down. It appears that some override system could be built in to allow for semi-automatic or manual operation in such cases. The production meter consists of a cross-point display (Figure 7).

Production is shown in tons per minute or cubic yards per minute and a totalizer provides values in tons or cubic yards. A nuclear density meter manufactured by IHC Holland uses cobalt 60 as the radioactive source (Figures 8 and 9). The velocity shown on the cross-point display is from 0 to 30 ft per second. A series of problems were encountered with the calibration circuits of the meters. On the magnetic flow meter, the liners have been replaced once since the dredge was built (Figure 8). Also the cobalt 60 source was replaced once. The bubbler is maintained at about 45 psi and is cleaned remotely once per year; the unit was made by Observator.

The dredge has an automatic light mixture overboard system (ALMO). This system has operated well and has never given any problems since it was installed. The discharge velocity is controlled by automatic control valves. The velocity limits can be set and the system is working well. A fully automatic system is also available but has never been used.

The hopper loading measurements and automatic draft and trim controller are also made by Observator. The equipment has not been found dependable because of the weirs in the hopper, which is an ongoing problem. The problem is of a mechanical nature rather than computer, the computer appears to be working well. Alarm panels have been installed to show the hopper overload, the maximum draft and no load draft. This system has proven to be quite dependable although overheating presents some problems. The alarm panels are installed in a vertical console and overheating creates some problems. There is also a list alarm. Some problems were experienced with the alarm system.

The WHEELER has an automatic dredge pump speed control, the computer works well; however, they have experienced problems with the mechanical part of the system in the engine room. The automatic dredge pump speed control has not been used.

There is also a master dredge computer, which has only been used for about 30 minutes during the last 5 years. It is considered totally unnecessary and is not used anymore. Several other automatic controls have been installed; the automatic mode master panels, automatic suction tube

controllers (ASTC), the drag arm position indicator system (DPIS), which indicates the angle measurement. Drag head depth indicator and DPIS work well. The ASTC system can work separately. As far as the dependability of the equipment is concerned, there has been a constant headache during the last 2 to 3 years due to transducers failing, cabling failing and pinched wires. There have been no problems in the last 2 years after installation of the new transducers.

Dump interface processor units have been reasonably dependable; only for a few days in recent years did they not work properly. The only problem at present is overheating in the console. Drag arms are operated manually or automatically. The gauges show the angle of the drag, the depth of drag head and location of the low section of the drag arm. It is surprising that there was no visual display of the drag arm. There is a swell compensator on all drag heads. The swell compensator signal is displayed on the drag-tender's panel. The flow into the hopper is controlled by angles and flaps, there is a display of the whole piping system with valves shown in open or closed position and the flow of dredge material for the various piping systems.

The hydraulic system to operate hopper doors is good. The solenoid operated valves have no any problems unless there is some debris in the system. The dredge has a hopper door interface relay computer, there is also a stress monitor which is designed to reduce stresses on the doors and it has operated well. The WHEELER has a direct pumping-out system from the hopper that has never been used.

MEMORANDUM FOR THE RECORD

SUBJECT: Visit to U.S. Army Engineers Dredge McFARLAND (trailing suction hopper, 3,140 CY, 6,000 HP)

We visited the U.S. Army Corps of Engineers Dredge McFARLAND on May 18. Captain Lambert took us around the dredge and showed us the instrumentation installed on the dredge. The dredge was built in 1964 and most of the instrumentation had been installed in later years. The drag-tender controls dredging by looking at the gauge showing the power deployed on the pump. The automatic control on the pump is based on the power used. The pump operates between 100 amperes and 2250 amperes. For example, when the discharge or the suction line plugs up, the amperes go down which indicates to the operator that the pump is not operating at its desired capacity. The limits appear to be set by the brake horsepower-discharge curve that controls the efficiency of the pump. This system is now used instead of employing a vacuum gauge, although the vacuum gauge is also available on the panel so that the operator can look at it. The automatic control system is also available for pumping out dredged material through a pipeline, or in a sidecasting mode. The automatic control system works reasonably well. However, closing of the valve by a pneumatic system is quite slow but a spring allows the valve to open faster. Other instrumentation includes the draft fore and aft, depth of the keel with respect to the bottom and pressure reading on the swell compensators. The Hofer valve system is installed on the dredge, however it has not been used. The load meter is shown in Figure 10.

The instrumentation showing the power input into the pump is available at the deck control room. The water jets are in the hopper and can be used to loosen up the hard-packed sand.

Navigation of the vessel is facilitated by a gyro which provides automatic direction of the vessel corrected for wind speed.

A very modern radar system is installed on deck that displays the direction and speed of an approaching vessel. A display is on the enhanced vision screen, clearly visible. The system called ARPA uses radar and is manufactured by RACAL DECCA model 2690BT series. In addition to the position of the vessels on the display, the following are shown on the screen: CPA, TCPA, true course, true speed, true bearing, range and true vectors (Figure 11).

A Mini-Ranger is used for positioning and is calibrated every 8 days. The Cubic navigation computer made by Western Data is checked every day. A Bausch and Loumb plotter shows the position of the vessel.

The drag-tender has an automatic drag location display; the alarm light goes on if the drag head is over a pipeline or under the bow of the dredge.

Bow thrusters are also available for maneuvering the vessel and for making sharp turns.

There are two locations for operating drag arms, one on the starboard and one on the port-side of the vessel. Displays are at both locations, showing direction, course bearing, and deviation from the course.

There are plans to install one set of controls in the middle of the captain's deck for both drag arms. There are also plans to put additional computers on the dredge. It is planned to change the job description for one of the electricians to an electronic technician.

MEMORANDUM FOR THE RECORD

SUBJECT: Visit to Dredge ALASKA (cutter suction, 30-inch discharge pipe, 9,700 HP)

We visited the Cutterhead Dredge ALASKA on May 18, 1989, operating in the Southwest Pass of the Mississippi Delta. The instrumentation related to production includes a doppler velocity meter and a nuclear density meter. The doppler meter is installed in a discharge line with two probes at an angle of about 40 degrees. The nuclear density meter was installed in a 30-inch pipe about 5 years ago (Figure 13). It was manufactured by Texas Nuclear, Inc. The velocity meter is also installed in a 30-inch pipe (Figure 14). It is model 9700D system transducer; and there is no easy way to calibrate the meter against other measurements. The meter was calibrated by Texas Nuclear; its accuracy and actual field use is not known. The nuclear density meter is installed in a horizontal line on the discharge side of the pump. It is calibrated electronically and its calibration is checked occasionally. The density meter is installed in a horizontal line which, to our knowledge, is the only such installation in this position on any dredge.

The dredge had a cross point display installed at one time; however, it did not work properly and it was removed. A new density meter was delivered to the dredge, but not installed as it was transferred to another dredge. As far the reliability of the meters, no problems were encountered with the density meter which was installed about 5 years ago. There are problems with the doppler meter. The density meter at the leverman's panel (Figure 12) indicates specific gravity of about 1.2 to 1.3 for dredging silt and up to 1.4 for dredging sand. Pressure gauges show pressure at the ladder pump and at the main pump in psi. The underwater pump is powered by a 1200 hp motor and the main pump is powered by a 7200 hp motor. Different diameter impellers can be installed in the main pump from 81-inch to 106-inch diameter, depending on the length of the discharge line. Since the dredge was working on short lines during our visit, there was an 81-inch impeller installed in the pump. The RPM on the main pump can be varied from 260 to 300 rpm. The cutter speed is about 21 rpm. The ladder pump contains a 68-inch diameter impeller with three vanes.

To obtain the best efficiency, the leverman basically watches the power input in kilowatts, the vacuum gauge and the density gauge.

The positioning system is made by Del Norte; it shows the range direction in degrees and feet sailed since the last setting.

MEMORANDUM FOR THE RECORD

SUBJECT: Visit to Dredge SUGAR ISLAND (trailing suction hopper, 3,600 CY)

A visit was made to the Hopper Dredge SUGAR ISLAND on August 1, 1989. Two dredges, SUGAR ISLAND and DODGE ISLAND, were operating in Cape Henry Ship Channel off the Virginia Coast. The dredges are owned by North American Trailing Company (NATCO). Captain Joe Bradshaw is in charge of SUGAR ISLAND. NATCO owns four almost identical dredges SUGAR ISLAND, DODGE ISLAND, PADRE ISLAND and MANHATTAN ISLAND. The first two dredges have a pumpout capability and were employed in the Cape Henry operation since some of the dredged material was used for beach replenishment at Virginia Beach and required a pumpout capability. About one million cubic yards of suitable sand were placed on the beach. After filling its hoppers, the dredge sails to a single-point buoy, attaches its discharge line to a pipe on a buoy and pumps out the dredge material through a submerged line to the beach. The pumpout is facilitated by water jet monitors installed in the hoppers. The unsuitable material for beach replenishment is discharged from the hoppers at a designated offshore disposal area.

<u>Production-related Instrumentation</u>

Instrumentation on all four hopper dredges DODGE ISLAND, SUGAR ISLAND, PADRE ISLAND and MANHATTAN ISLAND is identical which permits a quick interchange of a failed instrument; i.e. an instrument from an idle dredge or a dredge undergoing maintenance in a drydock can be temporarily removed from that dredge and used to replace a faulty instrument on a working dredge.

The instrumentation consists of nuclear density meters (manufactured by Texas Nuclear Co.), magnetic flow meters (manufactured by IHC Holland) and drag positioning equipment (manufactured by Observator Co.).

Nuclear density meters are installed in a vertical line between the magnetic flow meter and the main pump (Figure 16). The density meters have performed well since they were installed in 1986; only two circuit boards were replaced during a three-year period. Parts for the density meters are stored on the dredge.

Magnetic flow meters are installed in the vertical discharge line above the nuclear density meters. Magnetic flow meters are all original equipment installed in 1986 and nothing has been changed.

There are no production meters on these four hopper dredges; the production is estimated from the digging time and from the pre- and post-dredging surveys. The drag tender can observe the velocity in the discharge pipe (from the magnetic flow meter), the specific gravity of the material being dredged (from the nuclear density meter), and the load in the hopper (from the sensors in the vessel) (Figure 15). The operators feel that this system is probably sufficient to obtain production estimates. There were originally cross-point displays installed on the dredges but were subsequently removed. The operators did not know why they were removed. Echo-sounding records are performed daily by NATCO for their own benefit, presumably to improve the accuracy of production estimates.

On cutterhead dredges the magnetic flow meter is installed between the ladder pump and the nuclear density meter. The nuclear density meter is in between the magnetic flow meter and the main pump. Both the flow meter and the density meter are installed in the horizontal line. The main reason for the installation of the magnetic flow meter in the suction line is the low pressure.

Other instrumentation includes a hopper load indicator (made by Observator Co.) and load indicator. There are three pneumatic sensors on the drag arms which are subject to frequent repairs. The sensors were inspected after each load on this project involving dredging of hard-packed material. Teeth on drag heads and water jets had to be used on this project.

The displays in front of the drag tender include swell compensator pressure, jet pump pressure, dredge pump RPM, dredge pump SHP, pump suction vacuum and pump discharge pressure. Other displays show the velocity in the discharge line and specific gravity of the material being pumped.

MEMORANDUM FOR THE RECORD

SUBJECT: Visit to Dredge STUYVESANT (trailing suction hopper, 9,180 CY)

A visit was made to the M/V STUYVESANT operating in the Newark area navigation channels on November 13, 1989. The vessel is operated by Stuyvesant Dredging Company of Metairie, Louisiana. The address of the company is 3525 N. Causeway Blvd., Suite 612, Metairie, Louisiana 70002-3635, telephone (504)831-0880, telex 11 810 951 5152, fax (504)837-0407. Captain Samuel R. Pecota is the Captain of the vessel. The STUYVESANT is the largest hopper dredge in the United States. She has a hopper capacity of about 8,000 cubic yards and was built in Avondale Shipyards in 1982.

The dredge was designed by Bos Kalis Company, the Netherlands; most of the equipment and instrumentation is of Dutch origin.

Production-related Instrumentation

Instrumentation consists of magnetic flow meters, nuclear density meters and a production rate display (Figure 19). The instrumentation was supplied by IHC Holland. The hopper loading rate, total hopper load and trim displays were supplied by Observator Company.

Magnetic flow meters are installed in discharge pipes above the nuclear density meters (Figure 18). Inclination of one discharge pipe (on the starboard side) is 45 degrees and on the port-side about 50 degrees. One of the magnetic flow meters failed about a year ago and has not been replaced to date. It is speculated that there was something wrong with the magnetic coils.

Nuclear density meters are installed just below the magnetic flow meters in discharge pipes inclined about 45 and 50 degrees. Density gauges have cobalt-60 nuclear sources; the sources were installed in 1982 and they had the same strength of 981 m Curie of cobalt-60 in April 1980. A survey was conducted on October 7, 1986 using a Victoreen 470-A Meter. The source strengths at that time were 416.9 m Curie, or they had about 42.5% of their life left, and were thus not as efficient as when originally installed. The density meters were getting low in their ability to penetrate through silt. The cobalt-60 source has about a 5-year useful life and a half-life of 6 to 7 years, and the new sources with 1.0 m Curie were installed on January 14, 1987. The units are relatively maintenance free. A wipe test is performed every 6 months. The calibration of the units is performed at the request of drag tenders, usually about every two months by the ship's electrician/electronics technician. A calibration was performed during the visit; it consisted of an "electronic" calibration with sea water following a procedure prescribed by IHC Holland. For the purpose of calibration the section of discharge pipe is filled up to a level above the meter with sea water using an auxiliary water pump. This is preferred to calibration with sea water flowing through a pipe.

APPENDIX D: MEMORANDA OF VISITS TO MANUFACTURERS

MEMORANDUM FOR THE RECORD

SUBJECT: Visit to Texas Nuclear, Baker Hughes Company

A visit to Texas Nuclear Company in Austin, Texas was made on March 28, 1989. Meetings were held with Tom Erb, who is in the Research and Development Division, Mr. Charles Jackson, Regional Sales Manager and Mr. Bailey Southerland, also Regional Sales Manager and Mr. Ben Mathes (telephone number 512/836-0801, fax 512/836-4377). Mr. Tom Erb (telephone number 512/836-8547) took me around the production facilities and introduced me to other personnel in the sales division. Texas Nuclear Company, which is now part of Baker Hughes Company, is a very diversified company which recently acquired Manning Company. The company makes measuring products for the mining and oil industry and also for the dredging industry. Some of the equipment manufactured include an alloy detector, nuclear activation equipment, silicon detection equipment, etc. Much of the equipment is very sophisticated and represents the state-of-the-art. The equipment for oil field work is extremely rugged. Equipment made for the dredging industry is less rugged. As for production equipment made for the dredging industry, their main competitor is K-Ray Company. The Texas Nuclear Company is of the opinion that they routinely provide more service to the industry than other companies after the units are installed.

Doppler meters - Doppler meters are installed either on the side of the pipe or both sides of the pipe. They may be of high frequency or low frequency. The higher frequency provides more attenuation and works well with less material being transported. The lower frequency provides less scatter and is generally used for the measurement of velocities in dredges.

Mr. Bailey Southerland has been involved with the sale of equipment to Ellicott Machine Corporation. Initially the nuclear density meters were not attached properly to the pipe; however, in more recent years their attachment is better and the components are glued to the pipe. Once this was accomplished, there was a big improvement in the reliability of the density meters. During the last 15 years they sold between 40 to 50 nuclear density gauges. On the large discharge pipes cobalt or cesium is used as a nuclear source. The software on nuclear density meters has been upgraded recently and found to be quite reliable and accurate. The company installed several density meters on dredges mining for gold and dredges operating on both the East and West Coast, and the Gulf of Mexico. They had a fairly extensive manual describing the inner workings of the nuclear density dredge that was fairly complicated to read and required some background in electronics. They now have a much simpler manual which allows troubleshooting by the person using the meters. The meter is calibrated with water having a specific gravity of 1.0.

Cross-Point Display - Cross-point display is calibrated in the plant for the given size of the pipe prior to shipment. The calibration range is usually between the specific gravities of 1.0 and 2.0. It is important to calibrate the meter for the right size of pipe. Problems encountered with cross-point display, usually in the field, are often traced to water, particularly salt water. The transducers must be sealed very carefully so

that the water does not prevent them from working properly. There have been no problems due to vibration as they are spring-mounted. The problems have been because of untrained personnel using them and also improper mounting. For example, in one case the transducers were mounted in an improper location, which was close to the point where cavitation occurred. The air content in the mixture being pumped also introduces error. They have sold very few cross-point displays to the dredging industry. In fact, they ceased making them. If a customer wishes to have a cross point display installed on a dredge, it is purchased from IHC Holland. The company provides a two-year warranty on parts and service.

Service is provided for all meters. Mr. Ben Mathes is in the office eight hours a day and the company encourages troubleshooting by phone. Mr. Mathes, with his long experience, is able to point out the various areas where there may be a problem; trouble may be detected by doing different checks on the meter. If replacement is required, such as a circuit board or some other part, it is air-freighted to the contractor. The use of spare parts on the dredge is encouraged. Once the trouble is detected, the part may be replaced and the meter can be back in operation in a short time.

The microprocessor has self-diagnostic tests on new equipment and the overall reliability of the meters has been improved in recent years. A major problem with the nuclear density meters is the air content in the mixture; the density meter cannot handle air as it reads the density of the total mixture of air plus solids in water. Mr. Mathes estimates that 95% of the problems are solved by phone.

Cobalt-60 nuclear source has been used on several of the Great Lakes dredges and the meters have been in operation for about 5 years without changing the source. Other problems mentioned included Manson Construction Company in California that lost a circuit on a 4-year old gauge. In some cases, punching wrong numbers or playing with the computer may have caused problems. A password is now required to operate a computer.

The company sold eight meters to NATCO and they have had no problems. A problem was encountered on an installation for the North Carolina District of the U.S. Army Corps of Engineers. Apparently the range of densities was erroneously specified. Other problems encountered were due to inexperienced personnel using the meters by entering wrong information into the computer. The company now requires entry codes so that only authorized personnel can have access to the computer. Another problem deals with pipe wear. Pipe wear corrections must be made when excessive pipe wear occurs.

The Doppler meters are not as accurate as magnetic flow meters; however, the cost differential is so large that some of the contractors have purchased doppler meters for larger size pipes since the magnetic meter costs are quite high. The doppler meters are not as accurate as the magnetic flow meters. The company feels that accuracy is about 5%; however, there are many questions raised regarding the accuracy of the doppler meters and a lot depends on the installation, on whether they use the single meter, on one side of the pipe or two meters, etc. There are improvements being made in doppler meters and it is hoped to improve the accuracy of the meters in the future.

MEMORANDUM FOR THE RECORD

SUBJECT: Project 6211

Visit to Polysonics (R) at 3221 Marquart, Houston, Texas 77027. A meeting was held with Mr. Don Rodriguez whose phone number is (713) 623-2134.

The company specializes in non-contact ultrasonic flowmeters including:

a) POLYSONICS - Doppler
b) TYME-FLYTE - Transit-time, and
c) POLY-LEVEL - open channel.

The company has been selling Doppler-type meters since 1976.

A variety of meters are supplied to automating and processing industries, pulp and paper industry, municipalities to measure raw sewage flow, chemical refining, mining, food processing, steel industry, cooling water measurement, dredging contractors, etc. Meters are also sold to the U.S. government. Meters supplied to the dredging industry are a relatively small portion of the company's business.

Meters have been supplied to the following companies:

Kenner Marine, Laplace, LA
T.L. James Co., Kenner, LA
Bean Dredging Co., New Orleans, LA
Mud Cat Corp., St. Louis Park, MN
S and S Aggregates, Zanesville, OH
Pioneer Concrete of Texas, Conroe, TX
North Slope, Barrow, AL
National Dredging and Pump, Folcroft, PA
Dakota Pump Inc., Mitchell, SD
Choo Choo City Dredging, Chattanooga, TN
Miles Sand Ind., Wichita, KS
Christofolou, Glendive, MT
Eureka Sand and Gravel, Eureka, MA
Gravel Equipment and Supply, Amory, MS
Hubscher & Sons, Mt. Pleasant, MI
Van Dusselldorp Sand & Gravel, Colfax, IA
Assemblers, Inc., Davenport, IA

There are two types of meters supplied to the dredging industry; one is model LCDT, known as the Doppler ultrasonic flow meter that utilizes a single head, the other is the twin crystal transducer, that measures liquid velocity from the outside of closed pipes. The meters can be used on almost any pipe including cement-lined, ductile, iron, carbon, steel, PVC, FRP and stainless steel. In the dredging industry, the meters have been generally used on Schedule 80 and 40 steel pipes. The meters indicate the rate of flow in feet per second, gallons per minute, million gallons per day or in metric units as well as total flow in volumetric units. The sensor transducer is connected to a rugged box called NEMA-4x that is corrosion resistant, equipped with either air purge fittings or in a NEMA-7 explosion-proof enclosure which is used in hazardous areas. Model LCDT is used with a single transducer while model UFM84 uses a dual head transducer

to measure liquids containing entrained solids or air bubbles. The company recommends that a single transducer be installed approximately between 15 to 120 degrees from the vertical or a dual transducer installed on both sides of the pipe at the same general location of a single transducer; and as an option, two transducers can be installed on one side of the pipe. The company does not recommend placing transducers either on top or at the bottom of the pipe. The cost of the LCDT unit is $1,950 and the cost of the UFM84 unit is about $3,400. The company provides a two year warranty on electronic parts and a one-year warranty on workmanship.

Accuracy

The company claims an accuracy for both meters of 2 percent of full scale, and repeatability within 0.1 percent of full scale. The accuracy depends to some extent on the type of pipe used and this is why a prospective customer should specify the type of pipe used. Linearity is claimed to be 5 percent of full scale. Units can be calibrated in the field using an electronic calibration check on a given frequency.

Service

The service department is located at the Company's office in Houston, Texas. There is a toll-free number which is answered 8 hours per day. Generally, most of the problems can be solved by telephone and shipment of spare parts is made to the customer. Representatives in the field can generally recalibrate the meters; any major problems are referred to the service department in Houston. The service charge for field repairs is $500 per day plus travel. Recalibration is recommended every two years and maintenance every year.

Reliability of the Instruments

The company claims that the instruments are very reliable and many instruments have been in operation for a period of 12 years.

The company provided an Engineer's Users Guidebook for Doppler Flow Measurements in Liquids" as well as other Company brochures and reprints of the following papers:

Dellerson, A.N. (1983) Instrumentation Enhances Dredging Efficiency, published in *Dredging + Port Construction*, July.

Dellerson, A.N. (1984) Doppler Flow Meter, published in *World Dredging and Marine Construction*, May.

APPENDIX E. SELECTED ABSTRACTS

Dredge Data Logging System

by R. Anderson and L. Burk
Proceedings, *WODCON XII Conference*, Orlando, FL, May 1989, pp. 651-659.

The dredge data logging system (DDLS) is developed for the U.S. Army Corps of Engineers as a quality assurance tool to administer contract dredging. The system is designed to operate unattended monitoring all analog or digital sensors and computes the vessels positions to provide a complete record of activity, which is analyzed at a later stage to make predictions and improvements in the dredging system.

The DDLS consists of four separate units:

a. A.C. power conditioner (ACPC).

b. Signal processing unit (SPU).

c. Dredge data logging unit (DDLU).

d. Portable control unit (PCU).

ACPC and SPU are permanently installed on the dredge. ACPC provides stable power to all units of the system. SPU acts as a secured junction box where the parameters of each sensor are recorded on a floppy disk which is available for review on future contracts of that vessel. It also converts data formats into a useable serial string.

The DDLU is installed on a contracted dredge. It processes and logs the data received from the SPU according to preset parameters input by the quality assurance inspector via PCU. The main purpose of this unit is to provide a reliable monitor aboard each vessel with enough storage capacity of at least 30 days to reduce the number of visits to collect data from the dredge. The unit weighs less than 70 lbs, enabling easy transport.

The PCU is used in conjunction with DDLU to control and monitor the set-up procedures. The unit consists of a video monitor, keyboard, and a printer packed in a carrying case. It also has a cable storage, a bi-fold paper container for printer and a flat screen monitor with a small foot-print installed in the upper portion of the carrying case.

System uses Microsoft Quick Basic 4.0 system and integrated assembly language due to its powerful features. It is fast to code and execute; linkable to any Microsoft language and graphics are versatile.

For geodetic positioning the system uses Lambert Conformal and Universal Transverse Mercator projections; for offshore positioning it uses rapid least squares algorithm.

The function "auto scroll" automatically recenters the ship in a new grid each time its position reaches 90 percent of screens edge; the display grid can be viewed with the "zoom" function. Also, the "auto-start" feature brings the system back on line after a power failure or a system shut-down.

Software provides histograms or graphs for each selected sensor.

The advantages of the DDLU are listed below:

a. Reduces direct inspection overhead by reducing the time and effort required for inspection.

b. Increases efficiency and reduces cost for the total dredging industry through both real and post-time analysis of DDLS data base.

c. Reduces the dredging costs to the government in enabling proper use of dredging methods based on DDLS data analysis.

d. Reduces litigation and court fees to both government and contractor regarding performance as DDLS data provides a complete record of dredge activities.

e. Provides an on-going data base for scientific analysis of the dredging processes.

f. River sediment deposition can be modeled for future assessment of the nation's dredging needs.

Considering the above-mentioned merits, the implementation of the DDLS throughout the government and industry should not be delayed in order to improve future dredge specifications and efficiency.

Systems for Measuring and Controlling Dredging Processes

Anonymous
Ports and Dredging, No. 132, 1989, pp. 8-11.

Information concerning the solids concentration and the velocity of dredged mixtures is crucial for dredging efficiency. For optimum results, the solids concentration of the mixture must be as high as possible. The most widely used method for measuring the solids content of dredged mixtures involves the use of radioactivity. A velocity indicator must be capable of measuring the velocity at various points through the diameter of the pipe. Measurement at a single point cannot be employed with dredged mixtures, as is the case with the ultrasonic method. The electromagnetic indicator gives a correct mean value of the velocity of a dredged mixture.

Where space for installing the sensors is limited, it is advantageous to employ an integrated concentration and velocity indicator. Particularly where a vessel is operating at various locations, the integrated indicator provides an uninterrupted flow of reliable data.

The production indicator embodies the amplifier for the concentration and velocity indicator and also a microprocessor which computes the production in tons and cubic meters and adds up the values.

Measuring the Contents of a Hopper Dredger: A Dream or a Feasibility

by S.E.M. deBree and L.W.F. Joanknecht
Proceedings, *WODCON XII*, Orlando, FL, May 1989, pp. 919-936.

This article refers to the various methods of measuring the amount of soil transported by hopper dredgers.

A number of systems are in use to determine the load of a hopper; these systems rely upon measuring principles which differ from each other. A listing of the systems is as follows:

a. The displacement method - The displacement of the hopper suction dredger is determined by means of draught measurements and the associated, calculated displacement of water. The difference between a full and an empty ship provides the total load.

b. The hopper sampling method - One or more samples are taken in the hopper which are then analyzed. There is a great variation in sampling techniques as well as in the analyses, with the associated determination of the load.

c. The sounding method - This is used for combined loads, in which a so-called solid layer can be distinguished from a fluid soil/water layer. Sounding takes place, usually at a number of vertical cross-sections.

d. The pressure method - When carrying fluid loads, the density of the load can be determined by measuring the pressure in the hopper in relation to the height to which the hopper is filled (or the pressure difference along a calibrated height).

e. The hopper level method - During the last decade, measuring of the hopper level has been gradually introduced in a number of dredges. The measurement is supplementary to the preceeding methods. The main methods in use are acoustic. The acoustic sensors are very easy to obtain and relatively cheap measurements can be made without much maintenance.

It may be concluded that the best hopper level measurements can be made by acoustic sensors.

The paper gives the present state of art in hopper contents measurement. It may be expected that further developments and practical discussions will lead to:

a. New methods to replace existing basic measurements.

b. Methods for those basic measurements for which no operable system as yet exists which have shown in practice that are reliable.

A New Nuclear Density Gauge to Measure Directly High Turbidities in Muddy Areas

by A. Caillot, G. Meyer, D. Chambellan, J.C. Tanguy
Proceedings of the Nineteenth Coastal Engineering Conference, Vol. 3, ASCE, 1984, pp. 3172-3179.

Foreward

A better knowledge of the characteristics of muddy areas in access fairways and port basins, and of the behavior of ships during their crossing, presents the double interest of enhancing the navigation possibilities. A more precise adjustment of the underkeel clearance will permit a more rational planning maintenance dredging. Considerable savings will be obtained through the development of such information for harbor management.

These improvements imply the use of measuring equipment which must be handy, sturdy, reliable and which gives accurate measurements.

The JTD3 gauge presented by the Radioisotopes Applications Service of the French Atomic Energy Commission is an important step in the development of such measuring equipment. It is now in running order, and commercially available, after thorough testing undertaken during many months in different French harbors.

New developments are already in practice as turbidity gauges can make dynamic measurements.

Introduction

The depth necessary for sailing, including the free space between the keel and the bed of the channel, is called the underkeel clearance. However, in muddy areas, it is quite possible for ships to sail through non-consolidated silt without reducing safety.

The usual method to determine the water depth is based on the traditional hydrographic survey - the upper trace recorded by an echosounder appears as the bottom of the channel. In these circumstances, it is very difficult to say exactly where the channel depth is, and the maintenance dredging takes two aspects:

- when, where to dredge and to which depth?
- how to control dredging costs?

In assessing the nautical as well as the dredging aspects, an important factor is density of the silt/water mixture. For this purpose, a nuclear scattering gauge, called SAPRA JTD3, has been developed to measure the vertical density (or concentration) profiles as a function of depth.

Principle

- Gamma rays emitted in all directions by a very small cesium 137 sealed source are scattered through the sediment.
- The detector is shielded from direct gamma rays emitted by the source by the means of a conically shaped tungsten plug set between the detector and the source housing.

- Gamma rays emitted by the source interact with the electrons of matter in two ways:
  - compton effect.
  - photoelectric absorption.

The diffusion effect is nearly independent of the chemical composition of the sediment.

Conclusion

In muddy areas, such as access channels and harbors, where repeatable in situ measurements of the density in sediment layers are necessary, the SAPRA JTD3 gauge and the echosounder are useful instruments. The employment of a nuclear gauge permits the optimization of the dredging process.

Mass Flow Measurement and Control in Mining and Mineral Processing

by R. E. Charles

Bulletin, Fischer and Porter Company, Pub.No. 16361, August 1964.

This paper discusses mass flow measurement techniques for liquids and solids slurries. The primary measuring devices, the magnetic flowmeter and the gamma gage are obstructionless on-line devices which cause no restriction to flow. Not only can the weight of the slurry itself be determined, but if the density of dry solids flowing in the pipeline is known and is constant, then the mass flow system can produce data which represents the weight of dry solids flowing in the pipe.

A mass flow loop is an extension of standard process instrumentation which permits readout in mass units. Functions of the mass flow loop are:

a. Measurement of fluid velocity.

b. Measurement of fluid density.

c. Multiplication of these factors.

Mass flow can then be recorded in any desired units of measurement.

Slurry velocity is normally measured with an electromagnetic flow meter. Two methods exist for measurement of density of the slurry flowing in the pipeline; a nuclear radiation gage or the use of one or more differential pressure transmitters. Hydraulic mining (or dredging) involves the movement of mineral bearing rock (or slurry) from the site to a processing plant (or disposal site) by pipeline. As more material is transported hydraulically in pipelines, mass flow measurement and control become necessary. The density of the slurry is controlled by the operator who manually adjusts slurry flowrate in order to control percent solids in the pipe. Mass flowrate could be computed by the solid-state electronic mass-flow computer and totalized on a solid-state electronic totalizer so that total tons per shift and total tons per month of material are available for management's review.

First Experimental Results on a Magnetoelectric Flowmeter

by D. Codazzi, J. Moncharmont and D.J. Pittman
Journal of Physics E: Scientific Instruments, Vol. 20, No. 8 January 1987, pp. 1041-1045.

The major difficulty encountered in the development of the magnetoelectric flowmeter is the low level of the flow magnetic field (2 pT $m^{-1}s$) along with much higher values of a quadrature magnetic field (several nanotesla) due to the displacement currents. The generation of high AC voltage in the audio range has undesirable effects. The technical solutions that were implemented can be summarized as follows:

a. The shield design of the detection coils must be such that good shielding efficiency is obtained against both displacement and conduction-current magnetic fields. Shielding against these stray fields relies on either absorption in a thick permeable material or on a low-reluctance shunt path. An important feature of the shield design is the small thickness of the shield material along the flow channel, i.e. where the flow magnetic field should thread the coils. At this strategic place, the quadrature displacement magnetic field is perpendicular to the flow magnetic field and the shield's thin permeable walls provide a low-reluctance shunt path, hence preventing these unwanted fields from threading the coils.

b. The balancing of the polarizing circuit is enhanced by the split-electrodes technique and double connection. Fine tuning of the system balance is performed on the low-voltage side of the step-up transformers. Significant background signal reduction can thus be obtained.

   The performance of the magnetic field detection system is also enhanced by careful pick-up coil design.

c. A natural tendency would be to use detection coils with a large number of turns. But it appears that a symmetrical assembly of low-capacitance coils made with only 1000 turns along with the use of ferrite cores is more satisfactory. The choice of the operating frequency (10 kHz) is also important.

Common practices in low-level measurement techniques which include filtering, grounding, shielding, signal source impedance balancing and of course, phase-sensitive detection are of prime importance.

With respect to possible industrial applications, the results are not very satisfactory because of the complexity of the equipment required to detect the extremely low-level signals generated by the motion of the fluid.

Ultrasonic Flowmeter Tests With Slurries

by J.M. Colwell, C.A. Shook, R.G. Gillies and M. Small
Journal of Pipelines, Vol. 7, 1988, pp. 127-140.

The performance of Doppler and transmission ultrasonic flowmeters has been examined for a range of slurry flow regimes and particle sizes. The experiments used three sands of differing particle diameter and two sets of polystyrene beads. The velocity and concentration distributions of these slurries were known from extensive previous investigations.

The results of the study indicate that though the Doppler meter measurements were fairly close to the true velocities, neither type of meter is suited for a broad range of slurry flow. Systematic deviations were found to be related to the concentration and velocity distributions and to the effect of particle diameter on the penetrating power of the beam. The transmission flowmeter was unsuitable in coarse slurries or at high concentrations of fine particles.

However, the results were within the normal laboratory standards of accuracy. For practical applications, where a greater uncertainty is acceptable, these devices are undoubtedly useful.

Dredging Flowmetering Techniques

by R.A. Denning

Proceedings of the World Dredging Conference, 1971, pp. 611-644.

Various techniques for measuring the velocity and density of solids-water mixtures flowing in dredge pipes are described, including some of their advantages and disadvantages.

Since velocity changes are transmitted almost instantly, it is not important where velocity is sensed along the pipeline. However, the dredge should ideally be equipped to measure density as near the suction inlet as possible. Instruments in present use are usually installed near the dredge pump resulting in an output which is delayed about 10 seconds after the material has passed the suction head.

The differential pressure method can also measure velocity and density. It is not suited for velocity measurement since it involves some form of restriction in the flow line, however, the elbow meter is obstructionless and has a much lower initial cost. For density measurement, the response time is poor when using differential pressure technique, and regular maintenance of the purge system is required.

Doppler shift and beam deflection methods are not recommended for velocity measurement since they depend on the velocity of sound which varies significantly with the solids content of the flow mixture.

Some of the other techniques described in the paper are the transit-time technique, thermal flowmetering technique, weighing technique, electrical conductivity techniques and resonance techniques.

Display systems are also described in the report. The cross-point indicator provides measures of flow velocity, density and solids flowrate, each in a manner such as to avoid confusion between readings.

Experience With Ultrasonic Flowmeters

by E. A. DeVries
Hydrocarbon Processing, Vol. 65, No. 6, June 1986, pp. 65-66.

The purpose of this article is to review experiences, both good and bad, with both Doppler and transit time ultrasonic flowmeters.
The Doppler meter signal is reflected by particles, bubbles, or other discontinuities in the liquid, and the frequency is shifted by velocity of these discontinuities. Some limitations of the Doppler meters are that:

a. There must be particles entrained in the fluid.

b. A good flow profile is needed.

c. Doppler meter signals do not penetrate air, i.e., porous pipe materials such as concrete, concrete-lined, or many types of Fiberglas cannot be used.

d. They are affected by pipe temperature, pipe thickness and ambient extremes.

The principle strengths of Doppler flowmeters are the non-intrusive sensors and the relatively low price.

Another common type of ultrasonic flowmeter is the "time-of-flight" or transit-time meter. This meter uses two sensors that are lined up at an angle to the direction of flow, and that pulse alternatively. A time-differential relationship proportional to the flow is calculated. These meters are superior to the Doppler meters in terms of accuracy and repeatability, but they are more expensive, and made for cleaner applications.

Successful and unsuccessful ultrasonic flow meter installations at a plant are also reviewed. One Doppler meter was installed on a polymer slurry in the mid-1970s, but the results were poor because of lack of accuracy and repeatability. The Doppler meter was replaced with a wedge element flow meter which has worked out well. Another experience with the Doppler meter was when it was used for the centrate flow velocity out of a monomer slurry centrifuge. However, since the particle size and density did vary greatly, the meter was unable to get a repeatable signal. Magnetic flow meters are now employed in this plant.

Later successful application with Doppler flowmeters was achieved in the area of wastewater, chemical sludge flow, etc. Time-of-flight type ultrasonic meters are being used for molten sulphur service and have proved to be satisfactory.

Some microprocessor-based ultrasonic meters are introduced to overcome the limitations of ultrasonic flowmeters, but the prices of these new types are very high. For tough applications, magnetic flowmeters, coriolis-type mass flowmeters, or wedge element flowmeters are recommended. These meters are relatively expensive, but confidence in them is high.

Flow Measurement Techniques for Hydraulic Dredges

by Ernest P. Fortino
Journal of the Waterways and Harbors Division, Vol. 92, No. WW1, ASCE,
February 1966, pp.109-125.

It is generally acknowledged that the modern dredge, which is an expensive item, must be operated intelligently for maximum return of the investment.

To operate a dredge pump intelligently, the operator should know the following quantities:

a. Revolutions per minute.

b. Suction pressure (vacuum).

c. Discharge pressure.

d. Flow velocity.

e. Flow density.

The first three of these parameters can be measured by well-established techniques. The concern is primarily with techniques for measuring velocity and density quantities.

Pneumatic system - Differential pressure converters develop the velocity squared and the uncorrected density signals. These instruments have an input and an output side. The input side is the differential pressure sensing side. The higher and lower pressures are applied across a diaphragm, movement of which causes movement of a force beam in the output side of the instrument. The instrument is of the force balance type. The output side of the instrument is supplied with air pressure. Enough of this air supply is applied to the force beam to balance the effect of the differential pressure. The signal delivered is in the standard 3-15 psig signal band. Thus the instrument design is such that a 15 psig signal corresponds to the highest differential pressure, and a 3 psig signal corresponds to a zero differential pressure.

The main difficulty stems from entry and deposit of solids in the purge lines. To facilitate clearing these lines when clogging occurs, back-flushing connections are provided to force the solids back into the dredge pipe. Purge flow rates have been increased in newer systems. This rate cannot be increased without some effect on the ship's fresh water supply because it is desirable to use clean fresh water for purging as the use of sea water causes more difficulties.

Another difficulty arises from the inability of the system to maintain calibration for long periods of time. Wear in the dredge pipe, which causes changes in the developed differential pressures, is one factor.

Electric systems - Velocity is measured by means of a magnetic flowmeter. Such meters operate on the principle that the fluid is a conductor which develops a voltage proportional to its velocity. The degree of fluid conductivity has no effect on metering accuracy. It is only required that the fluid be conductive above a low minimum threshold value, approximately 20 micromhos per cm.

The meter is not affected by:

a. Temperature.

b. Density.

c. Viscosity.

d. Pressure.

The accuracy of this meter is within 1 percent to 2 percent of full scale velocity reading.

The electric system has problems, too, but they are less frustrating than the line-plugging problem of the pneumatic system. The electric systems are considerably more costly than the pneumatic systems and the electric circuitry is complex, well beyond the maintenance capabilities of the average dredge personnel. For some dredges the space required to accommodate a magnetic flow meter also becomes a problem.

The present aims are to continuously improve both systems to the point where each is reliable in operation and can be maintained without undue demands on the time of dredge personnel, and, having developed reliable systems, to ultimately use this instrumental intelligence to develop semi-automatic and possibly automatic dredging controls.

Report on Study of Master Meters

by Harold D. Gilman

Proceedings, AWWA Conference, 1981, Pt. 2. pp. 937-942.

The Distribution Division assigned the study of plant and pump station master metering to the Automation and Instrumentation Committee. The specific objectives were to review the state-of-the-art of master metering and to develop a committee report to identify and characterize the most important meters used in water treatment and distribution systems. Those listed include:

a. Orifice plate.

b. Venturi.

c. Flow tube.

d. Propeller.

e. Magnetic flow meter.

f. Ultrasonic flowmeter.

Orifice Plate - In the orifice plate meter, the flow is restricted by a thin plate inserted in the pipe with a hole of smaller diameter than the pipe. After passing through the hole in the plate, the fluid forms its own high-velocity, small-diameter flow section. The most common orifice plates are those with the hole concentric to the outside diameter.

Orifice plates are inexpensive, easily manufactured, and readily installed or replaced. They have no moving parts and are available in a wide range of sizes and constructions.

Some limitations on the orifice plate include:

- high non-recoverable pressure drop.
- deterioration of accuracy with wear and damage.
- the potential for solids build-up at the inlet side of the plate in a horizontally installed pipe.

Venturi - The venturi meter creates a pressure differential by gradually reducing the pipe diameter to guide the flow to the throat and then gradually increasing the pipe diameter. The venturi has a low permanent head loss and does not obstruct the flow of suspended matter. For the same pressure differential in the same size pipe venturies can measure 60 percent more flow than orifice plates. As for disadvantages, for a given line size the venturi tends to be heavier and larger than other pressure differential meters, and therefore more costly.

Flow Tube - Although similar to the venturi, the flow tube has a relatively short length of transition section from the inlet to the pipe throat, and a recovery cone of gradually increasing diameter. The flow tube causes significantly less pressure drop than the orifice plate, but is costlier. With its shortened inlet section, the flow tube is usually less expensive than the venturi for the same line size.

Propeller Meter - The propeller meter operates on the principle that water impinging on the propeller blades will cause a rotational speed proportional to flow. Basically a velocity measuring device, the speed is linear with flow change over the operating range. The gearing and drive shafts transmit the rotary motion to a mechanical counter or an electrical pulse generator for remote readout. Propeller meters can provide high accuracy over a 10 to 1 flow range and good repeatability. Having moving components, the meter is subject to wear. The fluid must be relatively clean and not of high viscosity.

Magnetic Flow Meter - The magnetic flow meter is based upon the principle of electro-magnetic induction, designed to measure the flow of conductive liquids in a pipe. As a conductive fluid passes through the metering section, the lines of force from the magnetic field are cut producing a low level voltage at the pick-up electrodes. This flow meter has no moving components. There is a completely unobstructed bore, and minimal head loss. They are highly suitable for slurries. Sizes range from 1 inch to 96 inches diameter. To be effective the fluid must be electrically conductive. The meter is more expensive than other meters, and there is the possibility of electrode fouling.

Ultrasonic Flow Meter - The transit time concept of the ultrasonic, or acoustic flow meter refers to the time required to convey ultrasonic pulses upstream and downstream as directly related to the fluid velocity. Acoustic meters can provide good long-term stability, are economical and accurate. They are non-intrusive, do not restrict pipe size, and have virtually no head loss. Air bubbles or solids, however, may disturb the penetration of the acoustic pulses across the full pipe diameter from transmitter to receiver.

Selecting and Applying Magnetic Flowmetering Systems

by M. F. Griffin

Water/Engineering and Management, Vol. 132, No. 12 November 1985, pp. 33-38.

The magnetic flowmeter was developed to measure the flow rate of viscous, corrosive and other difficult-to-handle "conductive" fluids.

Understanding the types of flow metering systems is important for selecting and applying magnetic flowmetering equipment. The two types discussed are:

a. AC systems.

b. Pulsed DC systems.

Both AC and DC systems have good accuracies. Pulsed DC systems are more accurate at low velocities and over a greater range. Pulsed DC systems perform best on homogeneous, non-pulsating processes. High solid-content, non-homogeneous fluids or pulsating flows should be avoided and are best handled by an AC system.

Another consideration is the tendency of the process to coat the wall of the flow tube. Where coating is possible,the pulsed DC system will generally be more tolerable and the least affected.

Energy costs are another consideration in selecting AC or DC. Pulsed DC systems are more efficient and consume less power. Power consumption for DC units ranges from 10 to 30 watts, while with the AC variety the range varies from 25 to several hundred watts.

Another area worth considering is the magnetic flowmeter installation. The general construction of both AC and DC flow tubes is similar; however, pulsed DC designs are available in compact and light weight forms, making installation in flow tubes under six inches in diameter possible by one person.

Further savings can be realized by virtue of the automatic-zeroing feature of the DC system which automatically sets the zero at no-flow condition. The AC system requires adjustment of zero under a no flow, full-pipe condition at start up; however, once the system is set it gives excellent long-term stability.

The magnetic flowmeter is an obstructionless device and virtually unaffected by changes in process variables. The AC systems provide the broadest application possibilities. However, pulsed DC systems provide high accuracy, wide range capability, and automatic zeroing for the measurement of homogeneous processes.

Design of Early Production Metering Needs System Approach

by Peter P. Jakubenas

Oil & Gas Journal, Vol. 84, No. 12, March 24, 1986, pp. 120-124.

Precise measurement of crude oil from early production floating vessels to ocean-going crude carriers is technically and economically feasible with properly designed metering and loading systems. The crude oil storage and transfer vessels are often termed floating production storage off-loading systems (FPSO). The transfer must usually occur at rates high enough to accomplish the complete unloading of the storage vessel into the crude tanker in 10 to 20 hours. Because of the problems associated with accurately gauging tanks under these circumstances, high flowrate liquid metering systems are very desirable.

Measurement of crude oil by metering instead of gauging of vessel storage tanks is preferable for the following reasons:

- It is more accurate (0.25 percent or better).
- It is more convenient for operation.
- Results are completely auditable and traceable to standards.
- A high degree of security and integrity can be built into the system if required.
- Readout of the final corrected data is available immediately upon completion of loading.

Measurement systems are used periodically and must be designed for simplicity of operation. The FPSO measurement system should include the following: automated valve control, sampling, proving, and readout of temperature, pressure, and gravity.

For proper measurement, air and/or gas must be eliminated from the flow by an air eliminator installed ahead of the meter runs.

Two types of meters are usually used: positive displacement meters and turbine meters. PD meters will be better if fluid properties are not completely known. PD meters have two additional advantages over turbine meters. They take up less space and are not subject to the unknown effects and the swirl of the approaching fluid stream.

For maximum measurement accuracy, precise temperature, gravity, and pressure signals must be sent from the meters to the control room. These signals must be isolated from other categories, namely power and control, by separate junction boxes and conduit or cable systems.

A Monitoring System for a Grabdredger

by J.W.M. Jansen
Proceedings, *WODCON XII Conference*, Orlando, FL, May 1989, pp.185-196.

Grab dredgers are extensively used in the construction of important structures like dams, breakwaters; the dredging and filling of trenches; the covering or uncovering of pipelines or tunnels; and maintenance dredging in harbors.

The components of a grabviewer are a monitor, keyboard and a set of sensors. Sensors used in the standard configuration are:

a. Slewing angle encoder.

b. Boom angle encoder.

c. Tilt sensor.

d. Wire length measurement.

The hardware consisting of a powerful 16 bit microprocessor, video controller board, a processor unit, a terminal strip and the software of the system are designed in the simplest way to enable easy operation. They are designed so as to accept any modifications even at a later stage.

The system has a small numerical keyboard for the input of parameters. From position display, a single keystroke brings the operator to main menu display enabling the operator to select the appropriate input page, and make corrections as required. All entries are maintained in a battery-backed RAM memory to be maintained in storage after a power breakdown.

For proper maintenance of the work progress and quality control, the equipment may be equipped with reporting facilities like hard copy or data logger output.

The position calculation of the grab consists of two parts.

a. Determining the position of the grab with respect to the crane axis:
The grab position is calculated using the boom angle, slewing angle, tilt angle and paid-out wire length. For greater accuracy, optional measurements like roll measurement, hoisting wire angle measurement, draught and tide connections, and jib angle are considered.

b. Calculation of the grab-position in absolute geographic coordinates:
Since the work involves many activities like stone dumping, dredging, filling, etc. over a layer area, the nature of the work to be done has to be defined in a local coordinate system, oriented along the centerline of the work.

The position of the slewing axis of the crane is entered as follows:

a. The position of the crane axis relative to the position.

b. The position of the reference point relative to the pontoon.

c. The position of the antenna in geographic coordinates.

d. The bearing of the pontoon.

After the establishment of the local coordinate system the operator can define the depth profiles taken to the centerline for the work to be executed by entering the order pairs (offset, depth).

The graphic display is used for presentation which consists of a combined top and side view and some numerical data. The top view shows the grid display, view port definition, profile lines, dump/dredge marks. The side view shows the grab depth relative to chart datum and waterline.

In order to ensure reliable and trouble-free operation of the system, certain measures like adjusting the boom depth either by addition or removal of extension sections; or fitting different attachments like clamshells, or grapples or hooks on the hoisting wire are taken.

To eliminate the exact mechanical alignment of the sensor, the system has to be calibrated for wire length and angle measurements.

Grabviewer is designed with many possible options and extensions which facilitate the operator to input the position of several special objects like landmarks and buoys to be displaced on the screen as symbols.

An important extension will be the ability to receive grid information and profiles from a connected computer and to send back position information, dumpmarks, etc.

How to Measure Liquid Flow

by George Katzenberger and Robert Baker
Pipeline and Gas Journal, Vol. 203, No. 5, April 1976, pp. 24-36.

Liquid flow measurements are often required in process monitoring and control applications. Many different sensors such as the orifice meter, flow nozzles, velocity head averaging probes, turbine meters, rotameters and magnetic flowmeters have been developed and are used most commonly.

The selection of the meter generally depends upon the quantity of material flowing through a conduit. There are certain performance criteria to be considered in selecting the flow sensors. They are:

a. Accuracy
b. Repeatability
c. Response speed
d. Readability
e. Capacity
f. Rangeability
g. Pressure drop
h. Fluid characteristics
i. Cost
j. Installation requirements
k. Maintenance requirements

The orifice meter is the most common liquid flow meter used in processing industries. It provides signals to indicate a pressure drop across the restriction. It is based on Bernoulli's equation where the flow is a function of the square root of the pressure drop, the proportionality constant being determined by the characteristics of the fluid and the restriction.

The orifice acts as a reduction in pipe cross-section, causing an increase in flow velocity with a corresponding drop in pressure. The maximum velocity and corresponding pressure drop occurs at vena contracta normally at about 0.35-0.85 pipe diameters from the orifice pipe.

There are many types of orifices, the sharp-edged orifice is the most commonly used, and it has an accuracy of 98 percent. The orifice type is selected based on the type of fluid in the pipe. Orifices are generally used for low velocity, clear and noncorrosive fluids. An orifice with β-ratio between 0.4-0.6 is recommended.

Orifice plates are generally installed between pairs of flanges for greater accuracy. The pipes on either side of the orifice should be smooth. Pressure taps are placed on either sides of the orifice. Based on the location of the pipes there are different types of taps like vena contracta, radius, pipe, flange and corner taps. The cost of the orifice meter is low.

Flow nozzles are head-loss sensors consisting of contoured restrictions with cylindrical throat sections These are advantageous for high velocity flows or for liquids containing limited percentages of solids. These nozzles are generally assembled between flanges. Differential pressure measurement taps are located at one-pipe diameter upstream and one-half pipe diameter downstream from the inlet face of the nozzle. Velocity head probes sense the difference between static and dynamic pressure in the

flowing stream and infers the velocity using Bernoulli's equation. The most commonly used velocity probe is the Pitot tube. Velocity head probes cause less pressure drops than orifice due to obstructionless flow, installation is easier; cost is less than orifice. Units are sensitive to flow density and viscosity and they handle slurries too.

Turbine meters are extensively used for in-line blending, eliminating mixing tanks. Accuracy for such applications are high. Rangeability of the meter is 15:1. Units are insensitive to fluid density but might be affected by viscosity. Turbine meters are not recommended for use with slurries. The downstream pressure must be maintained above some minimal level to prevent cavitation or flashing.

Variable-area meters or rotometers have tapered vertical tubes to enable the floats to rise and fall easily with the flowing fluid. This device is mainly used for the visual indication of flow. The advantages are: a) rangeability of 10:1, b) low cost in small sizes, c) good accuracy, and d) visible evidence for proper functioning in glass tube models. The disadvantages are its sensitivity to: a) viscosity due to viscous drag, b) density due to float buoyancy, and c) solid particles due to potential clogging. Bypass rotometers are extensively used as alternatives to differential pressure sensors for visual measurement of flow through orifice plates.

Magnetic flowmeters work on the principle that the movement of a conductor through a magnetic field produces a voltage. The output of the meter is independent of density and viscosity. However, its limitation is that the meter must be completely filled with liquid as the velocity is sensed and interpreted from volume flow rate. Magnetic flow meters are capable of measuring any fluid whose electric conductivity exceeds 0.1 $\mu\Omega$/cm, thus can be used for measurement of the flow of slurries. Sludge accumulation on electrodes is eliminated by pulsing ultrasonic energy at electrode tips. The magnetic flow meters have linear output characteristics. The rangeability is 100:1 and can be expanded to 3000:1. There are restrictions on temperatures of the fluid and they cannot be used to measure the flow of hydrocarbons.

There are several other devices available for measuring the liquid flow. The ultrasonic flow meter does not require obstructions in flow line and can be installed over existing pipes, having particular benefits in larger diameter pipes used in waste-treatment applications. Nuclear magnetic resonance meters are available for applications where obstructions cannot be tolerated and accuracy is critical. Fluidic flowmeters are used for pulsed output for totalizing or digital sensing applications.

The more advanced devices are highly integrated units and produce the usable outputs directly. However, the selection of these devices must be made on the overall system costs and performance capabilities rather than the specifications of the sensors alone.

Slurry Flow Measurement: **A Case History**

by Donald P. Malone
InTech, Vol. 32, No. 11, November 1985, pp. 59-62.

Slurry flow continues to present measurement challenges to instrumentation specialists. Not only do particles in the stream tend to cause erosion and fouling, but the fluid is often highly viscous and is likely to exhibit non-Newtonian behavior.

This article deals with a coal product H-coal. Coal is slurried with process-derived liquids, converted to liquid and gaseous products, and separated into refinery-like products. Measurement of the slurry flow rate was required in lines ranging from 0.038 m to 0.305 m (1.5 to 12 in.) in diameter.

Due to the presence of erosive particles in the stream and the need to measure flows with Reynolds numbers as low as 300, the flowmeters found to be feasible were:

a. Segmented wedge.

b. Venturi meters.

c. Quadrant-edged orifice.

d. Acoustic Doppler flow element.

Segmented wedge-head - Type flow elements utilizing triangular restrictors in the pipes have the following characteristics:

i. Flow rates were approximately 3.5 percent lower than the reference values obtained from measurements at the pump and the slurry preparation drum. The differences were within about 2.6 percent of the full-scale readings.
ii. No evidence of erosion was found in any of the wedges.

The only situation where another head-type meter would be more desirable is where pressure recovery is important.

Venturi meters - Out of four venturi elements installed for slurry flow measurement, three were unacceptably inaccurate due to the effect of low Reynolds numbers. Another venturi meter was used under severe service conditions, but the Reynolds number was in excess of 500,000. The venturi meters have the following characteristics:

i. Accuracy of within 10 percent of the actual flow,
ii. The meters were inspected after extended use. None showed any indication of erosion.

Quadrant-edged orifice - After 4000 service hours, the flow rate indicated by this meter was in agreement with process parameters. No evidence of erosion was detected.

Acoustic Doppler Flow Element - Acoustic Doppler flow element failed to operate properly on the slurry because the acoustic signals were too weak to overcome the attenuation caused by particles less than 5 microns in diameter.

The segmented wedge flowmeters proved to be the most effective of several primary elements used to evaluate H-coal slurry flow.

New Equipment Boosts Sand, Gravel Production

by John Marazzo
World Dredging & Marine Construction, May 1976. pp. 18-20.

Today's plant operators, dredging equipment designers and manufacturers are performing research aimed towards technical advancements such as dredge-feed monitorization and control, design and testing of equipment for deepwater digging applications, and excavating devices especially suitable to non-cohesive material.

To monitor and control the flow of dredged material, both the specific gravity and velocity of mixture must be known. There are metering systems available which not only provide instantaneous readouts of these two variables, but also integrate them to provide simultaneously an instantaneous reading of the production rate in tons of material per hour.

A production metering system affords the operator a means of controlling the rate of flow of slurry or mixture to the plant because velocity is a monitored variable, and can now be maintained relatively constant. Also, a production meter is a managerial tool in the form of an information system which aids in the analysis of dredge capacity, operator efficiency and deposit characteristics.

Although the metering system is an extremely beneficial system, the plant operator still cannot overcome the barometric pressure limitation in deeper-water dredging. One of the most recent solutions is the fully-submersible pump and drive unit. By submerging the pump and locating it closer to the mouth of the suction pipe, the barometric pressure limitation is eliminated; and by submerging the drive unit and closely coupling to the pump, the alignment, maintenance and durability problems associated with long drive-shafts are eliminated.

In the mining industry, the criteria for an excavating unit are that the unit should provide a constant rate of feed and a maximization of percentage solids in the slurry.

These objectives led to the development of the underwater wheel excavator which can best be described as eight cast steel bottomless buckets welded onto two steel rims. The advantages of a wheel excavator are the following:

- The wheel is capable of cutting while swinging in either the port or starboard direction. This causes less variance in the flow of material to the plant and overcomes the inefficiency.
- The wheel provides a positive mechanical feed to the suction pipe and permits complete recovery of all the material cut.

To combat the effects of inflation, environmental regulation and zoning restrictions, new technologies for the operating efficiencies and cost benefits required must be developed.

Development of Automatic Operation System Incorporating Fuzzy Control for Cutter Suction Dredge

by A. Miyake, I. Ofuki, K. Sotooka, T. Fujino, T. Iokibe and T. Yagi
Proceedings, WODCON XII Conference, Orlando, FL, May 1989, pp 139-170.

The purpose of the development of an automatic operation system incorporating fuzzy control for cutter suction dredges is to increase the efficiency over a skilled operator.

The fuzzy control system based on fuzzy inference and the expertise of a skilled operator (deals with the fuzzy logic "if -, then -") is combined with the conventional sequence control system (deals with binary logic "1" or "0") to express the characteristics which cannot be defined by the binary logic.

The component parts of the system are:

a. A dredge controller controls the entire system.

b. Fuzzy controller enables the operational know-how of a skilled operator to be utilized.

c. A sequence controller performs I/O signal control and various sequence control operations.

These controllers are connected via a local area network.

Dredge Control (DC)

- setting of dredging conditions.
- setting of control-target values.
- setting of load-limiting control conditions.
- playback operation.
- monitoring of dredge operation.
- logging of dredging data.

Fuzzy Controller (FC)

- management of control rule files
- fuzzy interference.
- monitoring of fuzzy reasoning.
- simulation.

Sequence Controller (SC)

- process I/O control.
- interlock control.
- forward shifting control.

The control system for automatic dredging operations contains the following six sub-systems. They are:

a. Automatic programmed cutting pattern operation - permits the selection of two modes for dredging:
   i. playback mode - the operation of a skilled operator is simulated.

ii. manual mode - dredging pattern is set manually by keying in parameters while watching the CRT display.

b. Control for maximizing dredging production - maximizes the production of soil dredged/unit time (flow rate x concentration).

c. Forward shifting control - advances the dredge from one span to the next automatically when the dredging of the first has been completed.

d. Load limiting control - reduces the load and avoids the damage to the dredging machine in adverse conditions.

e. Logging.

f. Monitoring.

A field test was conducted in Shibushi Bay, South Kyashee with a model of the prototype constructed in 1986 to evaluate the production during the automatic dredging operation.

It was operated both automatically and manually for comparison. The result was that it took 8 minutes longer for the automatic operation than the manual operation.

The discrepancies were due to the following criteria:

a. Dredging time.

b. Electrical current and current motor and soil concentrations.

c. Dredging production per unit time.

However, the system demonstrates that complete automation of the dredging process results in an efficiency that is comparable to that achievable by a skilled operator.

Furthermore, the automatic automation capability can be used to record and store the important operational expertise of experienced operators which in turn is used to train the new personnel. Besides cutter suction dredges, the fuzzy control applications can be extended to other types of vessels.

Development of Soil Type Detector in Dredge Pipeline

by Y. Okayama, H. Nishimura and M. Katoh
Proceedings, WODCON XII Conference, Orlando, FL, May 1989, pp. 171-184.

The main objective of the development of the soil type detector in a dredge pipeline is to determine changes in the type of soil transported in the pipeline in real time so as to facilitate control of the slurry velocity.

The detector consists of a vibration sensor, an amplifier, a FFT analyzer, data recorder, 16 bit personal computer, CRT display and a printer.

The function of the detector is to first amplify the vibration signals picked up from the pipe wall of the delivery pipe, analyze and compare with the known vibration characteristics of the soil types and identify the nature of the soil flowing through the pipeline.

For this purpose, a preliminary test was conducted in the laboratory to obtain the basic characteristics of the vibrations of the pipe wall during the flow on sand and gravel through horizontal pipes. A spectrum distribution for different soil types at different frequency ranges are plotted.

The flow condition of slurry in horizontal pipes is assumed using Durand's pressure drop equation:

$\phi = 400$ $\psi - 2.0$ for sand
$\phi = 160$ $\psi - 1.66$ for gravel

Graphs for pressure drop and vibration level versus velocity were plotted and the characteristics of the soil type were determined.

The results of the experiments were:

a. during independent sand or gravel flow, the spectrum pattern of pipe wall vibrations showed significant difference in high frequency zone.

b. The increase in vibration levels is proportional to the increase in slurry velocities.

c. At high concentrations, as the flow in the bottom of the pipe approaches the sliding type, the vibration levels also approach close to a certain value according to the soil type.

A field test was also conducted in the similar manner. The location of sensor the is very important so as to eliminate the influence of vibrations from the dredge pump and hence is located at the lower part of the floating pipe closer to the stern of the dredge.

The external input parameters, beside the measurement data for the detection equipment, were flow velocity, concentration, pump suction and delivery pressures, etc.

The computed and processed vibration data for a wide range of frequency spectrum are displayed on the CRT. For any frequency zones, the vibration

level ranges could be displayed in time series along with the vibration level layers for water, sand and gravel determined from the preliminary experiments displayed in different color ranges for easy identification of the flowing soil type in the pipeline.

The study on the practical application of the soil type detector utilizing vibrations in the pipe wall and investigation of the same in laboratory and field experiments proves that it is possible to distinguish between soil types from the vibrations of the pipeline.

An upgrade in automation techniques can be expected, if the results of this research are used in the development of dredge automation.

Laboratory Evaluation of Production Meter Components

by Virginia R. Pankow
Proceedings 22nd Annual Dredging Seminar/WEDA X Meeting, Tacoma, WA, October 1989, CDS Report No. 317.

This paper describes a laboratory test in which several density gages and velocity meters were evaluated for accuracy and reliability under controlled conditions of slurry type, concentration and velocity. Meter location on vertical and horizontal pipe sections was also examined. A closed test-loop at Georgia Iron Works, Inc. (GIW), in which slurry flow and concentration can be monitored, controlled and tested, was used for this research.

The Phase I series of tests were conducted with four different grain size materials, each at three different concentrations through a wide flow range. Phase 2 tests were conducted with two different types of materials of a single concentration through the same flow range as Phase 1 tests.

The results of Phase I indicate that the nuclear density gages had values within 1-5 percent of each other. The magnetic flowmeter had values within 4.7-5.7 percent of each other. However, the data for the Doppler flowmeters showed distinct differences among themselves. Though the data for each meter was fairly self-consistent, there were greater differences from the control meter when compared to the magnetic flowmeters. Slurry velocity had no effect on the magnetic flowmeters or the nuclear density gages, but did affect the Doppler flowmeter values. Slurry concentration seems to have only a minor influence on the meter values.

Phase 2 tests indicated that slurry type had only a minor influence on all the test meters.

It could be concluded that the most accurate flowmeters tested were (in decreasing order) magnetic, bend and Doppler. The density gages record more accurately when rotated 45 degrees from the horizontal axis of the pipe, but the preferred pipe orientation is vertical. The study indicates that for determining dredge production, the most reliable instruments are the magnetic flowmeter for slurry velocity and the nuclear density gage for density measurement.

Evolution Enhances Magnetic Flow Meters

by John Salusbury

Control and Instrumentation, Vol. 19, No. 2, February 1987, pp. 43-45.

Electromagnetic flowmeters provide an excellent solution to flow measurement problems in conductive liquids and in recent years have become widely accepted in industry because of their many advantages. These include no moving parts, no flow restrictions and very accurate measurements over a wide flow range. The article concentrates on the most recent developments with special emphasis on coil design which has played such a major role in reducing the power consumption of the flowmeter. Extensive work has been carried out in the area of coil design with the ultimate aim of reducing the flowmeter's power consumption. To achieve an intrinsically safe meter, its consumption must be reduced significantly to 0.5 watts or less. Energy recuperation techniques have been employed to use heat energy in re-energization of the field coils during the next cycle. This also produces a faster cycle time and improves the speed of response of the flowmeter.

New coils have been developed utilizing very fine wire to wind smaller specially shaped coils with almost 10 times the number of windings of conventional field coils.

The design innovations resulted in the introduction of the world's first two-wire intrinsically safe electromagnetic flowmeter. The microprocessor has also made a significant input in electromagnetic flowmeter design. These recent developments now enable magnetic flowmeters to be applied in areas where high accuracy and high integrity measurements are required. The most impressive development in recent years is probably the fact that unit cost and installation costs have been reduced considerably.

Improvements in Doppler Flow Metering: An Overview

by William T. Smith
World Dredging & Marine Construction, October 1985, pp. 20-24.

Doppler ultrasonic flow meters are rapidly gaining acceptance as a reliable method for measuring liquid flows. The initial design of the Doppler flow meter requires:

a. Suspended solids or gas bubbles in excess of 1 percent.

b. Full-pipe section.

c. Non-porous, homogeneous pipe materials.

d. Sonically-conductive liquids.

e. Externally clean pipe wall.

f. Adequate straight run of pipe.

As more testing was performed and application experience was gained, technology improved and along with it the reliability and accuracy of the Doppler flow meter. The Doppler meters are now used in much clearer liquids with significantly better accuracy and repeatability. These meters have also demonstrated superior performance to the widely accepted magnetic flow meters, while at the same time, saving installation and high maintenance costs.

A combination of the following improvements have made the Doppler a more valuable instrument:

- different operating frequencies.
- larger and better piezoelectric crystals.
- more stable circuitry.
- better signal-to-noise ratios.
- more experience; not in the laboratory, but in the field.
- analog signal strength meter.
- internal frequency standard for easier re-calibration.
- underground/underwater transducer head.
- new coupling compound for a wider temperature range up to 350°F.
- plug-in circuit board for easy maintenance, and an intrinsically safe barrier for use in a hazardous stable circuitry.

There are currently 26 Doppler flow meter manufacturers worldwide. The meters range in price from about $600 to $5,000. Doppler flow meter has successfully been used in pipes up to 12-ft diameter. Pipe materials that are suitable are PVC, stainless steel, FRP, cement-line pipe, ductile and cast iron, polypropylene, etc.

The Doppler flow meters are useful tools to measure liquid flows, but they still have some limitations:

- heavily scaled or coated pipes.
- excessive pump noise and vibration.
- pulsating flows.
- non-Newtonian liquids.
- some hydrocarbon-based applications.
- pipe skin temperatures exceeding 320°F.

Production Meter Helps Increase Dredge Production

by John E. Wells

World Dredging and Marine Construction, Vol. 10, No. 9, August 1974, pp. 14-16.

In modern dredging operations, management is faced with the task of making profits in an economic climate of a fairly stable price per unit work and rising costs for labor, equipment, fuel and maintenance. Business survival depends upon the ability to optimize the efficiency of dredging. The production meter presents to the leverman instantaneous displays of specific gravity, pipeline velocity and production rate as well as accumulated tally of solids deposited upon the bank. Measured production on dredges utilizing the production meter have increased 15, 30 and even 40 to 45 percent. Experimental results obtained on the Ellicott test facility illustrate that the curve for maximum production rate for any given line length peaks over a relatively narrow velocity range. Also, the longer the line length, the sharper the peak and the more critical the velocity. This shows that without an instrument such as the production meter, it would not be possible for a leverman to regulate his pump rpm, and hence pipeline velocity, with any degree of optimization.

Production rate integrated with time provides accumulated production which is accomplished by the accumulated production module and its readout displays instantaneously a running tally of total production.

Ellicott estimates the overall accuracy of the totalized production of their production meter to be about 5 percent. While the production meter is not a frail piece of equipment, neither is it perfect. It requires attention and maintenance; however, it represents a significant step forward in dredge instrumentation.

Doppler Effect Tied to Flow Rate

by Rod Yost

Water/Engineering and Management, Vol. 134, No. 3, March 1987, pp. 30-31.

Using an old physics principle that only quite recently has been incorporated in a variety of modern instruments, the Doppler ultrasonic flowmeter is being applied increasingly in the water/wastewater field. Flowmeters designed around the Doppler principle are widely applied in our industry to measure the velocity of sludges, slurries, sanitary and industrial wastewater, process chemical flow and other liquids containing suspended particles.

The Doppler flow meters use the theory of Doppler effect which postulates that there is an apparent change in the frequency of sound, light or radio waves as a function of motion. These meters consist of a transducer, a Doppler frequency receiver/conditioner and a transmitter. The transmitter sends a continuous ultrasonic signal through the pipe and into the liquid stream, and then the transmitted frequency is reflected back to the receiver. The difference between the transmitted and reflected frequencies is displayed on a flowrate indicator in velocity units.

Generally, Doppler flow meters measure virtually any size pipes flowing full with minimum liquid velocities of 0.5 ft/sec under certain conditions. The most accurate readings are taken when the devices are measuring liquids that follow Newtonian flow profiles. Since pipe materials respond to Doppler signals, the pipe material must be considered and allow penetration of the ultrasonic signals. PVC, plastic, aluminum, cast iron, carbon steel and ductile iron with one of Epoxy coating or cement lining responds to Doppler signals excellently. However, copper, concrete and copper nickel alloys prevent penetration of the ultrasonic signals.

Significant technological improvements have been made recently in the three elements necessary for advanced Doppler flow measurements. They are: a) liquid excitation, b) the detection/collection of Doppler signals, and c) the signals processing/spectrum analyzing the signals received.

<u>Liquid excitation</u> - More efficient transmittal of power gives better liquid excitation with RF (radio frequency) energy operating at the higher energy level which:

a. Overcomes the resistance of pipe wall material to pass sonic energy.

b. Allows more RF energy into the liquid to produce higher quality Doppler signals.

c. Detects the unwanted signals such as vibration and other interference.

<u>Detection/collection of doppler signals</u> - Large receiver crystals are used to act like an antenna to collect Doppler-shifted signals. Also, newer integrated circuits have been incorporated to facilitate the collection technique of Doppler frequencies.

Signal processing/spectrum analyzing - To discriminate against unwanted scattered frequencies and retain the "true" flow-related Doppler frequencies, a spectral analysis is utilized. The true Doppler signals which are commonly referred to as "Doppler Shifts" are then converted to indicate liquid flow velocity.

Accuracies of 2-5% of actual calibrated flow range are significantly better than the earliest designs which had accuracies of 10-15%.

Some of the benefits of Doppler flow meters are:

a. Easy to install and operate.

b. Installation outside the pipe, no pressure drops and no internal assemblies to corrode or foul.

c. No moving parts to wear out or fail mechanically.

d. Easy to re-install and re-calibrate.

Advanced Control Concepts for Hydraulic Dredging and Mining

by Antonie C. van Zutphen
Proceedings, *WODCON XII*, Orlando, Florida, May 1989, pp. 123-138.

This article deals with both the good and the bad aspects of the advanced concepts of controlling the hydraulic dredging and mining with the man-machine interface system.

Formerly, when manually controlled operations for hydraulic dredging were prevalent, only two parameters were considered and the rest ignored as they were beyond human capability. This led to the introduction and adoption of sophisticated automatic ancillary units to monitor and control every single parameter involved in the dredging process which gave more accurate results leading to greater efficiency of the system.

The system basically consists of two units. The main unit is located in the dredging console on the bridge of the dredges and the secondary unit is situated on the navigation console, provided with a quick and easy access to both units. The secondary unit enables the read out, control from the second point and acts as a lock-up in case of the failure of the main unit. The control functions are relatively coupled with the relevant presentation in accordance with the action involved.

The process involves three phases - preparation, execution and termination. The functions of the control systems are:

a. Presentation of data.

b. Control of the dredging installation.

c. Monitoring of actions.

d. Automation of various functions.

The automatic control facilities available before and during the process are:

a. Mechanical handling of the suction pipe.

b. Hardware status.

c. Dredging start-up includes the lowering of dragheads on to the bottom and the transfer to the dredging mode.

d. Dredging -
- - draghead visor control.
- - pump speed control.
- - mixture control.
- - monitoring and control of the position of suction pipe(s).
- - control of hopper charging process.

e. Termination to cease dredging and return the suction pipes to the starting position.

f. Discharge of soil.

Proper design and use of the power plant reduces the number of motors and generators and lowers the operating and maintenance costs. Further,

positioning of the dredging element in horizontal plane also leads to greater efficiency and economy.

The main drawback of this system is the lack of manual skill to control the system if failure occurs.

However, the system avoids excess of hardware; offers flexibility in case of addition of new functions and adaptation to meet the future development; leads to highly efficient operation of the dredger in terms of optimum use of men and machinery; increases the efficiency and economy of the system.

Automatic Systems for Cutter Suction Dredgers

by A.C. van Zutphen
Dredging + Port Construction, March 1984, pp. 21-25.

Development of instrumentation and automation systems for cutter suction dredgers has been a topic of extreme interest over the last 20 years. Operators as well as manufacturers recognize the value of reliable equipment and its influence on the efficiency of dredging operations. The automatic cutter controller system was designed in close cooperation with the owners and incorporated information signal generators, an automatic control unit and a reporting system. The information signal generators are units that are also installed on non-automated dredgers to provide the operator with visual readouts. These readouts keep the controller informed of varying circumstances during the dredging process and the measures required to maintain maximum production efficiency.

The dredged profile monitor shows an exact image of the shape of the channel, the corresponding location of the cutter, and a set of numerical values for accurate reading of width and depth coordinates. The automatic control unit keeps track of the information signal values and movements of the dredge in response to the commands given by the dredgemaster. The automatic cutter controller continually adjusts the control parameters to the external circumstances. This, in turn, ensures stable control actions in relation to various soil densities and various load distributions between the cutter, side winches and pumps. A keyboard is used to give the commands to commence or interrupt the dredging process, to select manual or automatic presentation of environmental data and for manual for automatic control of spud carriage and ladder winch operations. Linked to the information signal generators as well as to the automatic cutter controllers, the reporting system gathers information for the compiling of progress reports, as well as data for research purposes.